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INTRODUCTION TO TEXTILE CHEMISTRY

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TORONTO

INTRODUCTION TO
TEXTILE CHEMISTRY

BY

H. HARPER

A.R.C.Sc. (Lond.), B.Sc., A.I.C.

FELLOW OF THE CHEMICAL SOCIETY
HEAD OF THE CHEMISTRY DEPARTMENT, THE TRADE AND GRAMMAR SCHOOL
AND TECHNICAL INSTITUTE, KEIGHLEY

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PUBLISHERS' NOTE

By the Education Act, 1918, provision is made for a large extension of the work of the Elementary School. Central Schools may be established in which, at appropriate stages, practical instruction suitable to the ages, abilities, and requirements of the better pupils must be given. Courses of advanced instruction for older pupils remaining at the elementary school beyond fourteen years of age must be provided, and measures taken for the preparation of those children who desire further education in schools other than elementary. It will be necessary also to arrange for a sufficient supply of continuation schools for young people between fourteen and (at present) sixteen years of age, the instruction in which must extend, within the working day, to 280 or 320 hours in each year, at the option of the local education authority.

A new type of book will be required for purposes of instruction in the new schools created by the Act; and the Life and Work Series is intended to supply it. The volumes in the series will be designed to satisfy two distinct ideals—one cultural and the other utilitarian or vocational—and in both cases the appeal will be through interest. It is not necessary to accept Rousseau's doctrine that a pupil should learn no lesson of which he does not feel the present need, yet he must have a consciousness of value if a dynamic response is to be secured. While the aim of education is to train young people to be worthy and working members of the community, the immediate task of the teacher is to detect incipient growth towards the light and to encourage it.

Contact with life and work will, therefore, be the common bond of the series. Compulsory attendance at school may be prescribed, but compulsory attention must come from the pupil's own being, and it can be just as successfully and usefully stimulated by the wonders or achievements of science and industry as by masterpieces of art and literature. Interest in the principles and processes of daily work is as worthy as a regard for what are called cultural studies, and both will foster a desire for further knowledge. Citizenship implies not only duty towards life in the community but also efficient work on its behalf on the part of the individual. It is hoped that the volumes in this series will, by their close touch with reality, satisfy the vital needs of young students and provide the nurture and stimulus which are the essential functions of all educational effort.

PREFACE

In the following pages a short account is given of some of the important properties of the textile fibres and the materials used in their treatment, but the chief object of the book is to provide a series of experiments illustrating these properties, in order to interest students of the various branches of textile work in the materials with which they deal. All the experiments can be carried out with the equipment found in an ordinary chemical laboratory.

Purely mechanical processes have been either omitted or treated very briefly, sometimes being merely mentioned. The principles of chemical reactions underlying manufacturing processes are dealt with in a simple manner, and should be readily understood by any reader who has an elementary knowledge of Chemistry.

Twelve years' teaching on the lines indicated in the book has convinced the author that students of textiles can be made to take a wider view of their own particular branch of the industry with ultimate benefit to the other branches.

The author is greatly indebted to the Editors, Sir Richard Gregory and Mr. A. T. Simmons, for much helpful criticism; to the various firms for kindly supplying drawings and photographs of their machines and plant; and to Mr. A. Langhorne of the Keighley School of Art for the microscope drawings of textile fibres.

H. HARPER.

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CHAPTER I

INTRODUCTION

TEXTILE FIBRES

Classes of textile fibres. The term, **textile fibres,** is applied to all fibres which are suitable for use in the manufacture of textile fabrics. Such fibres may be arranged into two groups, viz. natural and artificial, and the natural fibres may be further divided into animal, vegetable, and mineral fibres.

The representatives of the different classes are as follows :

Natural :
- Animal : wool, hair, silk.
- Vegetable : cotton, flax, hemp, jute, ramie, etc.
- Mineral : asbestos.

Artificial : the various artificial silks, the relatively unimportant spun glass, and metal threads.

Physical properties. The physical properties of a fibre determine its usefulness for the manufacture of particular fabrics ; and of these properties the most important are :

(*a*) Length or staple, and uniformity of staple.

(*b*) Tensile strength, by which is meant the force or strain to be exerted in the direction of the length of the fibre in order to break it.

(*c*) Pliability, which admits of the fibres being twisted together with little tendency to untwist.

(*d*) Elasticity, or the tendency of the fibre to regain its original length after being stretched. The elasticity of a fibre is, however, generally given as the percentage increase of length of the fibre before breaking. This is the elongation.

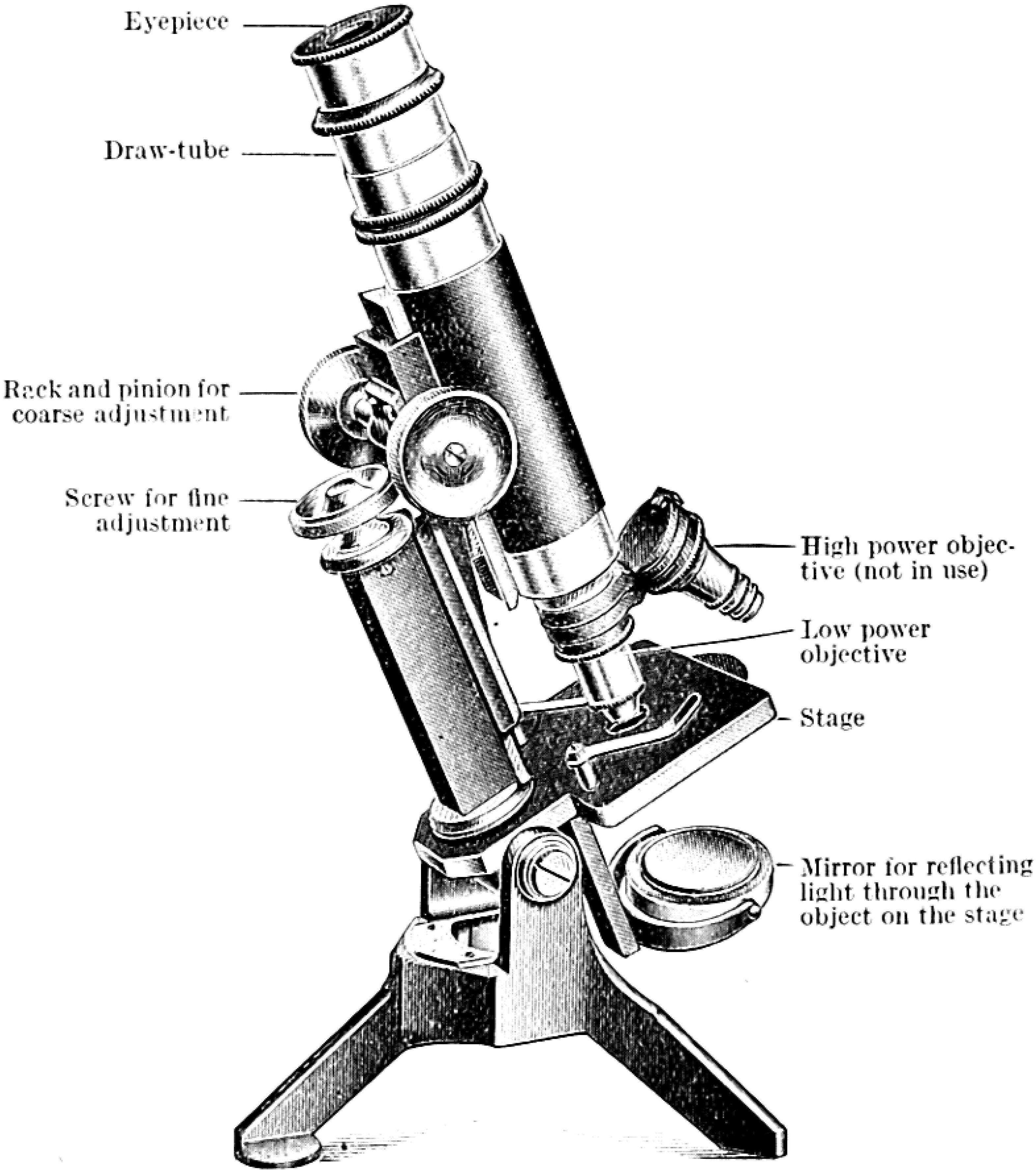

Eyepiece
Draw-tube
Rack and pinion for coarse adjustment
Screw for fine adjustment
High power objective (not in use)
Low power objective
Stage
Mirror for reflecting light through the object on the stage

FIG. 1.—The Microscope.

(*e*) Lustre.

(*f*) Durability or wearing quality.

(*g*) Conductivity for heat. Wool conducts heat badly, and woollen materials are therefore worn for warmth.

The fibre must also be cheap and obtainable in sufficient quantities.

Identification. Fibres may be identified by their physical properties and by their chemical properties; and the chemical reactions of the various fibres should be carefully noted in order that they may be used for identification. A collection of such reactions is arranged in tabular form at the end of the book. A very important method of identification depends upon the use of the microscope. The student should make himself perfectly familiar with this instrument in order to derive benefit from it. Much can be learned with low magnifications, say, of 50 to 80 diameters and, when experience has been gained with these, higher powers may be used.

Note.—Accustom yourself to use the microscope with both eyes open. If a sheet of paper or white cardboard be placed parallel to the stage of the microscope, the image of the object in the field of the microscope can be seen projected on it, and the outline of the image may be traced on the paper or cardboard.

EXPT. 1.—**Determination of magnifying power.** Place a stage micrometer, having lines 0·01 and 0·001 of an inch apart, on the stage of the microscope. Hold a diagonal scale, Fig. 2, parallel to the stage and read from it the distances between the lines of the stage micrometer as seen on the scale. Calculate

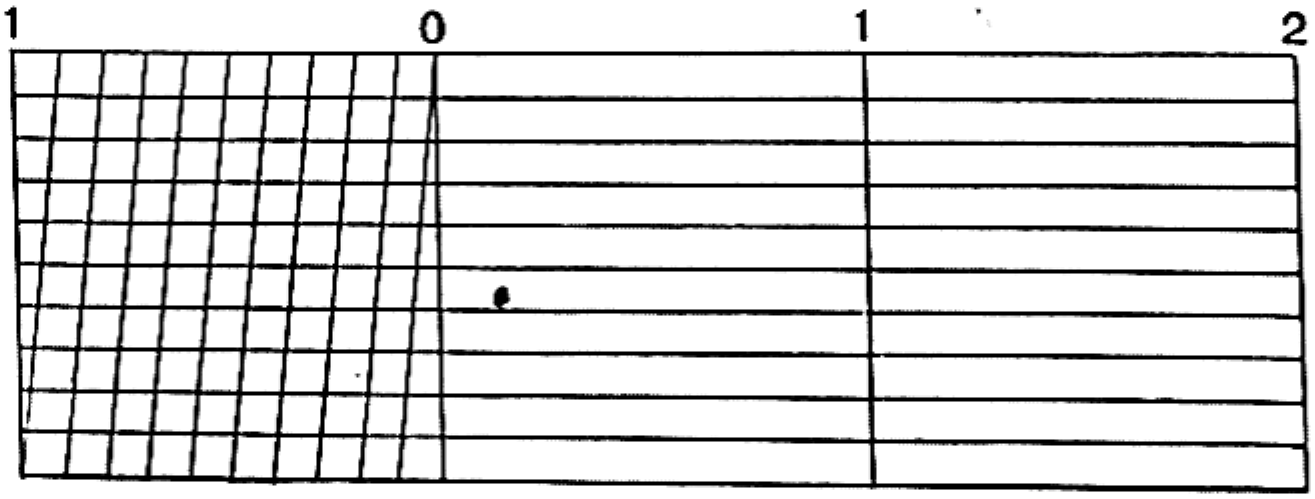


FIG. 2.—A Diagonal Scale.

from these the magnification. Use other objectives in the microscope and calculate the different magnifications produced. Lines running from side to side of the stage are easier to read than those from front to back. If the magnifying powers of the microscope are given in the microscope box, compare your results with them.

EXPT. 2.—**To measure the thickness of a fibre.** Place the fibre across a slide on the stage of the microscope and read off the diameter of the image as seen on the diagonal scale. Divide the result by the magnifying power of the instrument to find the true diameter of the fibre. Find the thicknesses of at least six different fibres, and compare your results with the following:

Kind of Fibre.	Diameter in inches.
Leicester wool	0·00181
Australian merino	0·00052
New Orleans cotton	0·00097
Egyptian cotton	0·00072
Raw silk	0·00070
Flax	0·00063

EXPT. 3.—**Characteristic appearances of fibres.** Examine, sketch, and describe the appearances of wool, hair, cotton, flax, raw silk, boiled-off silk, etc. under the microscope, observing the ends and intermediate portions of the fibre. Note the scaliness of the wool fibre, the absence of scales of hair, the pointed ends of lambs' wool, the twisted appearance of cotton, the central canals of many fibres, etc.

Many chemical reactions may be carried out under the microscope, the fibre being touched with a drop of the reagent. These are called microchemical reactions.

QUESTIONS I.

1. Sketch and describe the appearance under the microscope of (*a*) wool, (*b*) cotton, (*c*) raw silk, (*d*) hemp, (*e*) jute.

2. Describe the properties on which the suitability of a fibre for textile purposes depends.

3. Describe carefully how you would determine the diameter of a textile fibre.

CHAPTER II

WOOL AND HAIR

Varieties of wools and hairs. Wools and hairs may be divided into the following chief varieties :

1. **Long wools**, such as those of the Leicester and Lincoln sheep.

2. **Cross-bred wools**, which are long stapled wools from many parts of the British Isles, the Colonies, and Argentine.

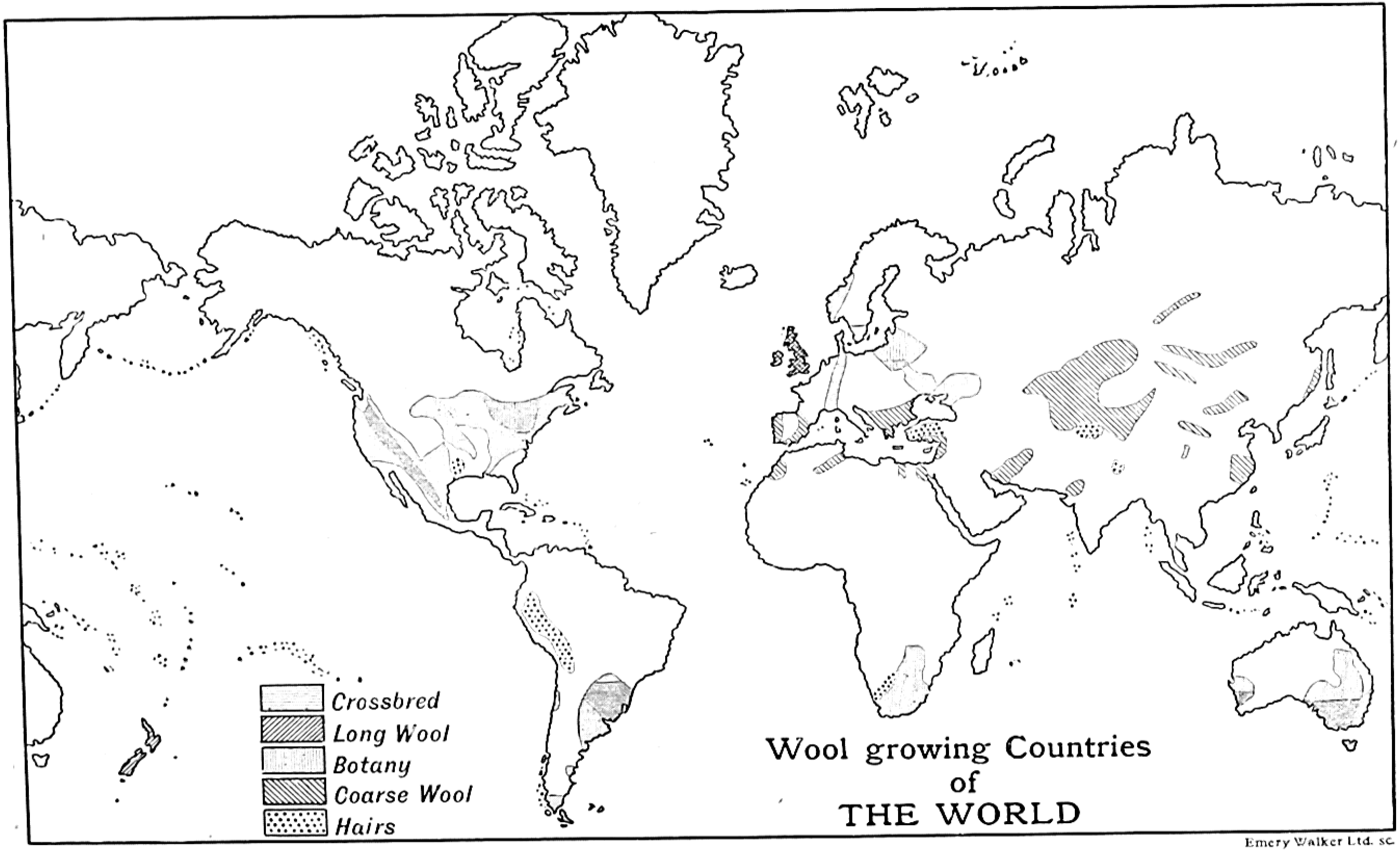
3. **Merinos** or **Botany wools** from Australia and South America.

4. **Mohair**, the long, stiff, silky hair of the Angora goat, originally from Turkey and Asia Minor, but now largely imported from the Cape, Australia, and the western states of the United States. It is chiefly used for dress fabrics, linings, and plushes.

5. **Alpaca** from the goats of Peru. This is also used for dress fabrics and linings.

6. **Cashmere** or **Tibet wool** from the Cashmere goat of Tibet. It is chiefly used for shawls and hosiery.

7. The hairs of the camel, cow, rabbit, horse, etc. **Camel hair** is used for making carpets, the noils being employed in the hosiery and hatting trade. The coarser qualities are used for belting and ropes. **Cow hair** is used for carpets, rugs, and blankets ; **horse hair** for upholstery ; and **rabbit hair** for hats.



Wool growing Countries
of
THE WORLD

Emery Walker Ltd. sc.

8. The various recovered wools, such as shoddy, mungo, extract wool, etc.

The skin of animals. The skin consists of two distinct layers: (*a*) the **epidermis** or upper skin, and (*b*) the **dermis**, *chorium* or lower skin. The epidermis is divided into the **cuticle** or horny layer and the **retemucosum.** The cuticle is composed of the dead cells of the underlying retemucosum, which consists of living cells. The dermis is divided into the papillary layer and the dermis proper, and consists of connective tissue filled with a network of

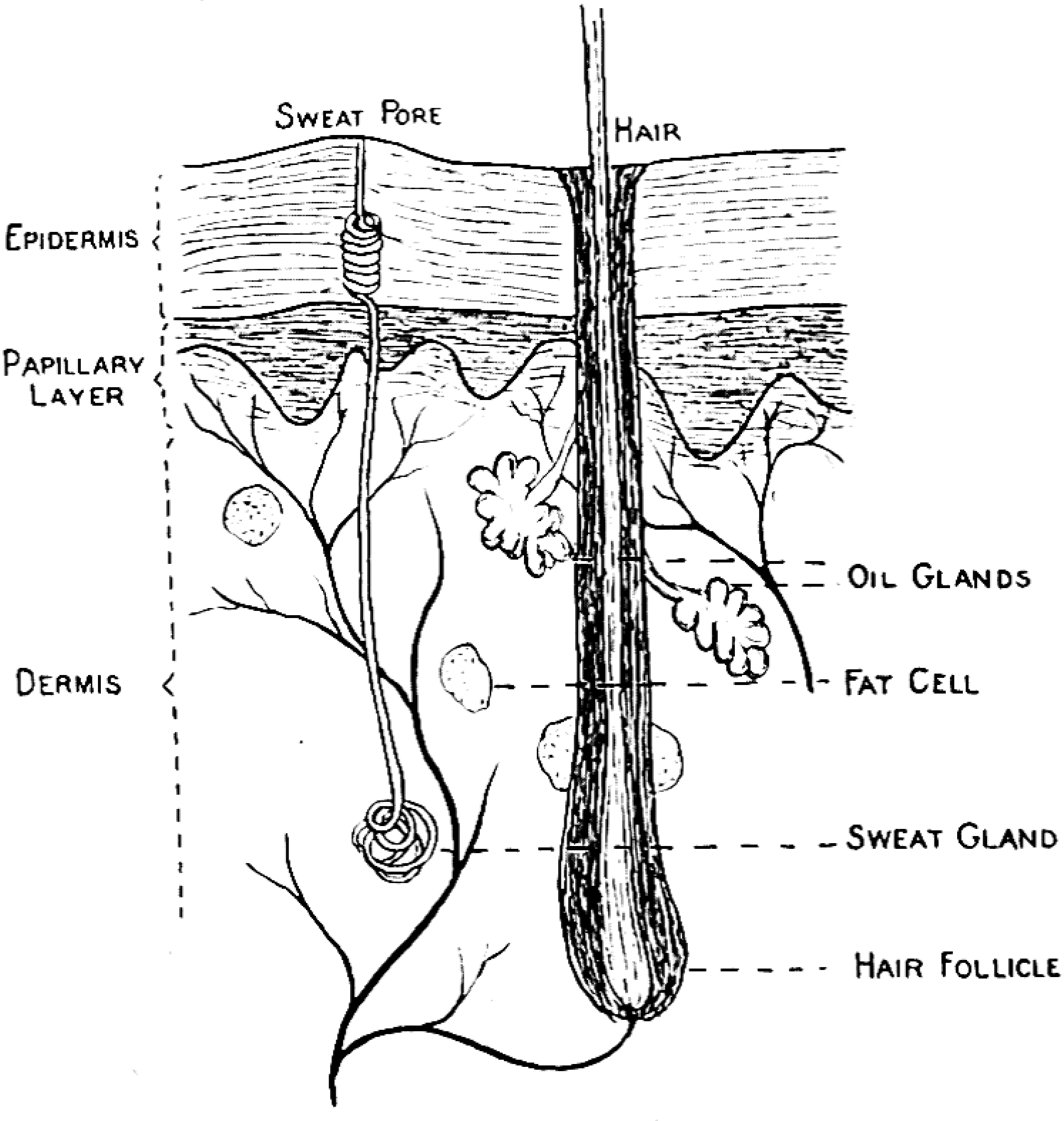


FIG. 3.—Section of Skin.

blood vessels, glands, and nerves. The nerves end in the papillae.

Glands. In the dermis there are two kinds of glands, the **sweat** or *sudoriparous* glands and the **fat** or *sebaceous* glands. The sweat glands open at pores in the surface of the skin and have a spiral form terminating in a complex coil in the dermis proper. They are organs of excretion, and by them water and waste substances are removed from the body. The sebaceous glands are pear-shaped and open into the hair follicle. They secrete and exude fat, which in the case of sheep constitutes the wool fat, yolk, or Yorkshire grease.

Nature of hair follicle and shaft. The surface of the skin is indented with pits or hair follicles from the base of which the hair grows. The walls of the hair follicles are composed of dermis lined with epidermis, and, at the bottom of the follicle, the dermis rises up into a vascular papilla which is furnished with special blood vessels to supply nourishment to the epidermal cells which are produced there. The multiplication of the epidermal cells

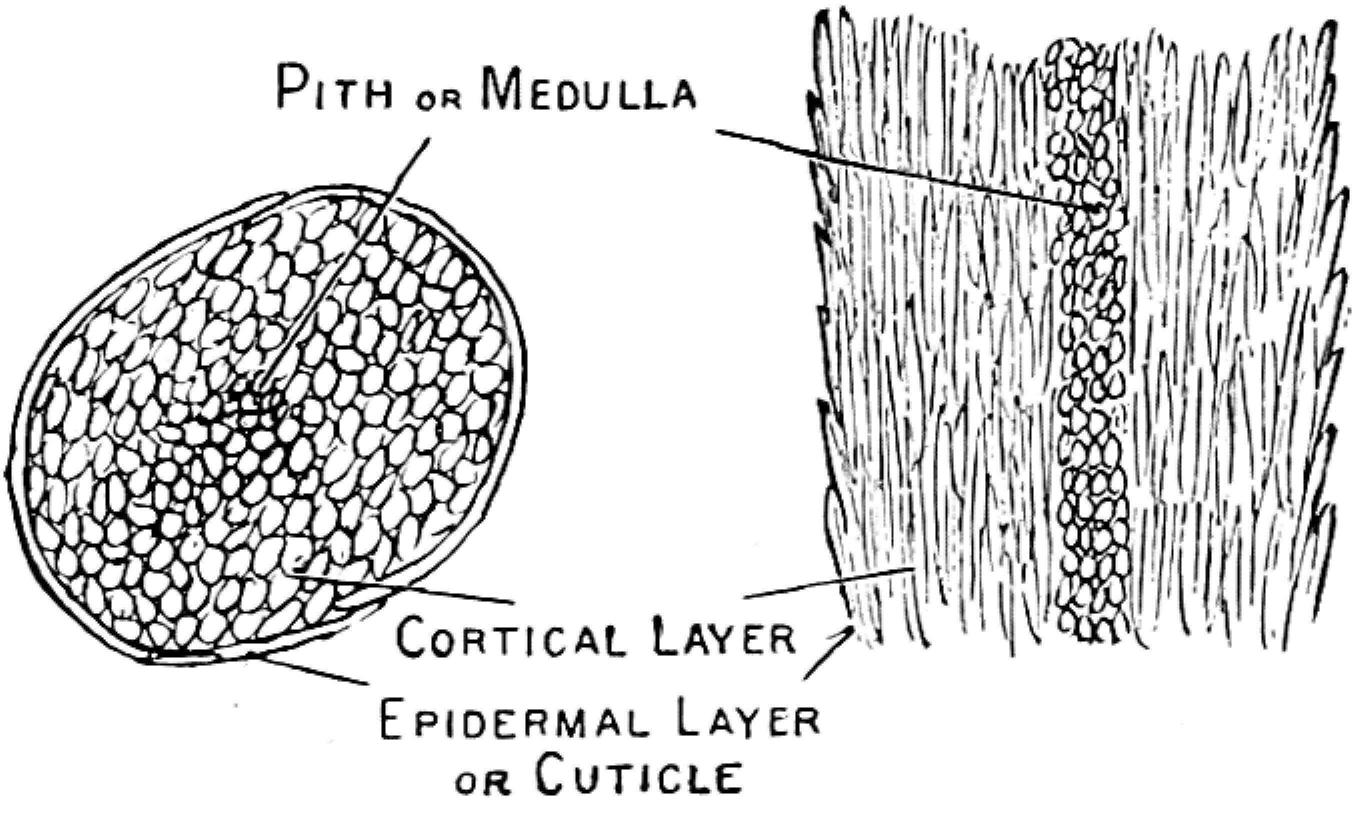


FIG. 4.—Sections of Hair.

over the papilla forms the shaft of the hair. As new cells are formed, the old cells, which join together and become horny, are thrust outwards, and so the shaft of the hair grows.

The shaft of a fully formed hair consists of:—

(*a*) a **pith** or *medulla*, loose in texture, consisting of angular cells, surrounded by

(*b*) a **cortex** or *fibrous* layer formed of dry horny spindle-shaped cells;

(*c*) a **cuticle**, which consists of overlapping lustrous horny scales or plates irregular in shape. The upper edges of the scales are free and the lower edges firmly embedded in the body of the fibre.

Wool and hair. No fine distinction can be drawn between wool and hair. In hair the scales are packed better, there being very few projections The fibre is thus rendered more lustrous and very difficult to mill or felt. Fine wools felt very readily and have no pith.

Kemps. In all wild animals there are two kinds of hair, a stiff hair and, underneath, a fine hair. In domesticated animals, such as sheep, the coarser kind is lost, but, if the animals are neglected, it will reappear. The stiff fibre is known as kemps. It is lustrous, cannot be milled, and lacks affinity for colouring matters. Owing to its stiffness, this kind of fibre is removed in combing. Certain wools—spoken of as dead wools—are harsh and brittle, and are obtained from diseased sheep. They often lack lustre and have less affinity for dyes than the average wool. The name, kemps, is also given to this class of wool.

Skin wools. Skin wools consist of wool removed from the skins of sheep slaughtered for food. They vary largely in quality according to the method used for their separation and also to the care taken during the process. The three principal methods of separation are :

1. The skins are hung moist in a closed chamber until putrefaction sets in and loosens the fibres. This process is used in the United States.

2. In England lime was used to loosen the fibres, but this left a harsh wool and one which, containing lime, formed lime soaps (p. 126) in the scouring. This method is now almost superseded by the sodium sulphide process.

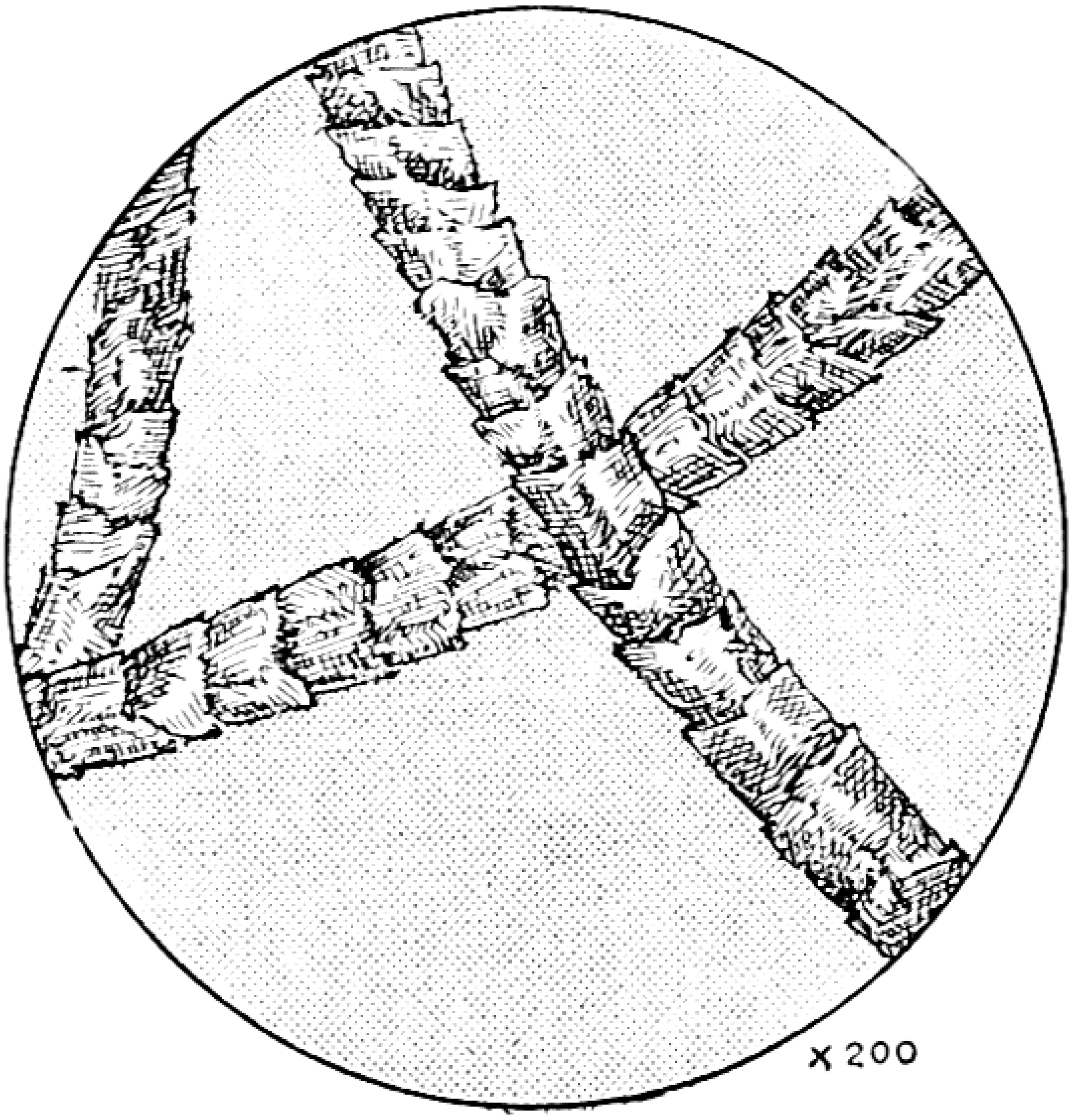


FIG. 5.—Microscopic appearance of wool fibres.

3. The skins after being washed are painted on the flesh side with sodium sulphide and allowed to stand overnight. The sulphide attacks the skin at the roots of the fibres, and the wool may readily be removed.

Microscopic appearance of the wool fibre. Under the microscope wool appears as an almost uniform rod covered with epidermal scales. In some wools the scales are very prominent, their edges projecting appreciably from the fibres, but in others the scales lie close against the fibres and are difficult to see. To the former class belong the fine merino wools, and to the latter, mohair, alpaca, camel hair, etc. Owing to the much smoother surface, the members of the latter class are more lustrous than those of the former. As previously mentioned, no true distinction can be made between wool and hair, one variety passing imperceptibly into the other. The fine wools have no pith or medulla, the free edges of the scales are generally straight, and a single scale is sufficient to surround the fibre.

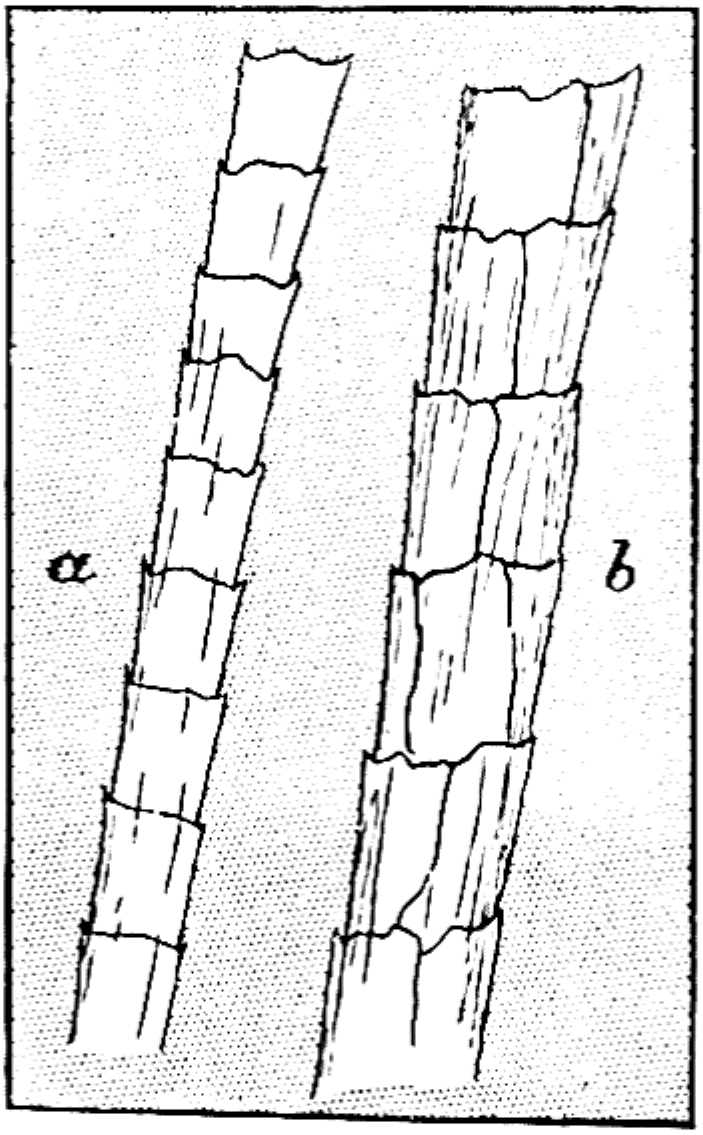


FIG. 6.—(*a*) Fine wool. (*b*) Coarse wool.

Felting. The felting of wool is sometimes attributed to the interlocking of the scales. The shrinkage may be illustrated by assuming that in this interlocking the fibres become crumpled and fastened in this state. Wools having the scales with greatest protuberance will, according to this,

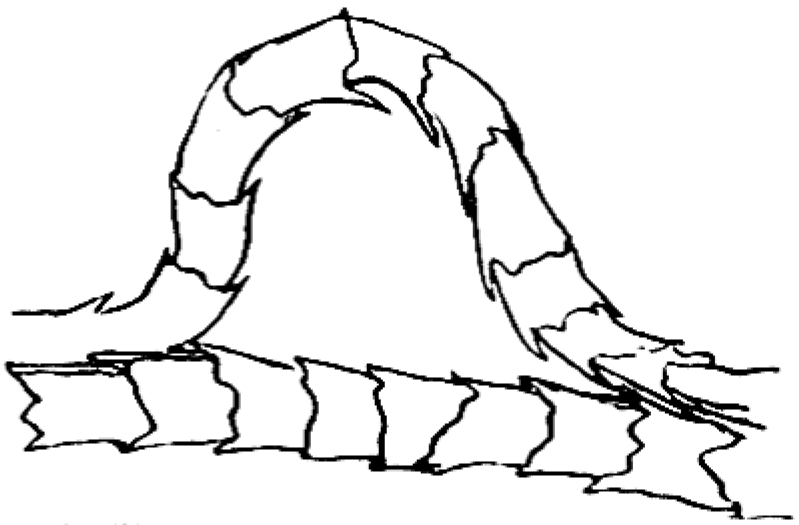


FIG. 7.—Diagram to illustrate Theory of Felting. Interlocking of Scales.

felt more easily than the others. Acids, alkalis, and hot water cause the scales to project more and thus assist felting. The curliness of the wool fibre is also given as a cause, if not the chief cause, of felting, but as the finest wools are the most curly (see below), and at the same time the most scaly, the question is rather difficult. It is, however, more probable that the scaliness and curliness of the fibres play only a small part in the felting and that the plasticity of the wool substance (p. 15) is the chief factor.

English merino	24 to 30	waves per inch.
Southdown	13 ,, 15	,, ,,
Lincoln	3 ,, 5	,, ,,

QUESTIONS II.

1. Describe the structure of the skin of animals, showing the sources of the perspiration and grease.

2. Describe the structure of the wool fibre, and point out the differences between coarse wool, fine wool, and hair.

3. What theories have been put forward to account for the felting of wool ?

4. What are kemps ? Point out the differences in the properties of kemps and ordinary wool.

5. What are skin wools and how are they obtained ?

CHAPTER III

THE WOOL FIBRE

Physical properties of the wool fibre. The wool fibre varies in length from less than 1½ in. in merino to as much as 20 ins. in some cross-bred wools (*e.g.* Leicester). The elongation is about 25 to 40 per cent., and the breaking strain varies from less than 3 grams in Saxony to more than 30 grams in Leicester and mohair. It is necessary, however, to remember that Saxony is a fine wool, and when equal areas of cross-section are taken, the Saxony is seen to have the greatest and not the least tensile strength. The following table gives a comparison of the tensile strengths of various fibres :

Fibre.	Elongation, per cent.	Breaking strain. grms.	Diameter. mm.	Tensile strength. gms. sq.mm.
Human hair - -	36·6	106	0·084	4783
Lincoln wool - -	28·4	33	0·046	4966
Leicester wool - -	27·3	31	0·042	5862
Northumberland wool	27·0	28	0·038	6176
Southdown wool -	26·8	5·9	0·025	3077
Australian merino -	33·5	3·2	0·014	5200
Saxony - - -	27·5	2·5	0·009	9831
Mohair - - -	29·9	38	0·043	6545
Alpaca - - -	24·2	9·7	0·014	15740
Cotton - - -	40·6	5·0	0·019	4925

The wool fibre is very hygroscopic, and is capable of taking up 40 to 50 per cent. of moisture without appearing very damp. **Conditioning houses,** where, among other things, the amount of moisture in wool is determined, have been established in various parts of the world, *e.g.* Bradford (Yorkshire), Roubaix (France), Turin (Italy), Vienna, etc. The conditioning is carried out by taking a representative sample of the wool submitted and suspending it in an oven heated to 110° C. until the weight becomes constant. The loss of weight is taken and the percentage of moisture calculated. The following figures are those allowed at the Bradford conditioning house:

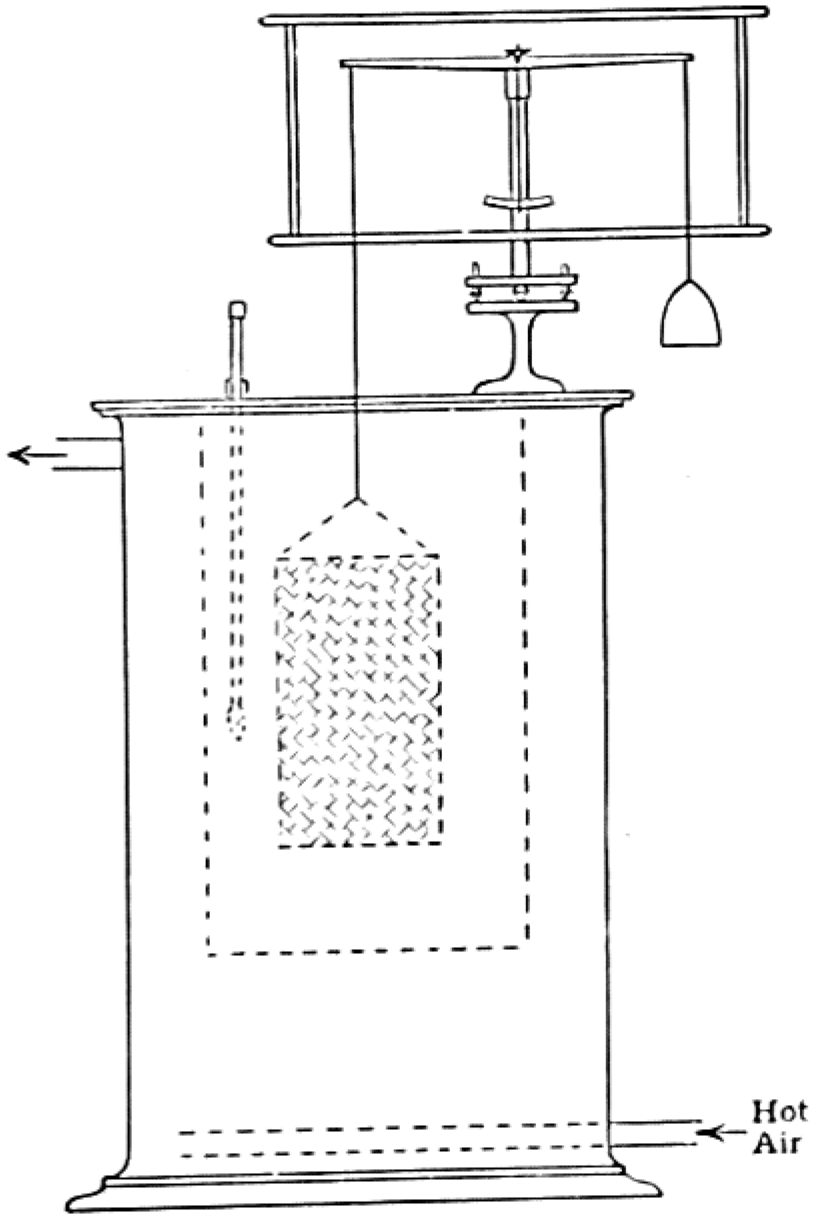


FIG. 8.—Conditioning Oven.

	Loss per cent.	Regain per cent.
Wools	13·79	16
Tops combed with oil	15·97	19
Tops combed without oil	15·43	18·25
Noils	12·28	14
Worsted yarns	15·43	18·25

A regain of 16 per cent. means that the normal wool (*i.e.* at the right condition) contains $100 \times \frac{100}{116} = 86{\cdot}21$ per cent. of dry wool or 13·79 per cent. of moisture.

EXAMPLE: A sample of raw wool was found to contain 12·30 per cent. of moisture. With a regain of 16 per cent., 1000 lb. of this wool would be equal to

$$(1000 - 12{\cdot}3) \times 1{\cdot}16 = 1017{\cdot}3 \text{ lb. of normal wool.}$$

The certificates issued by these houses are made the bases on which much wool is bought and sold.

EXPT. 4.—**Condition of raw wool.** Accurately weigh a sample of the raw wool, heat it in a conditioning oven at 110° C., or in a steam oven until the weight is constant. Calculate the percentage of moisture in the wool. Allowing a regain of 16 per cent., calculate how much normal wool is equal to 1000 lb. of the wool from which the sample was taken.

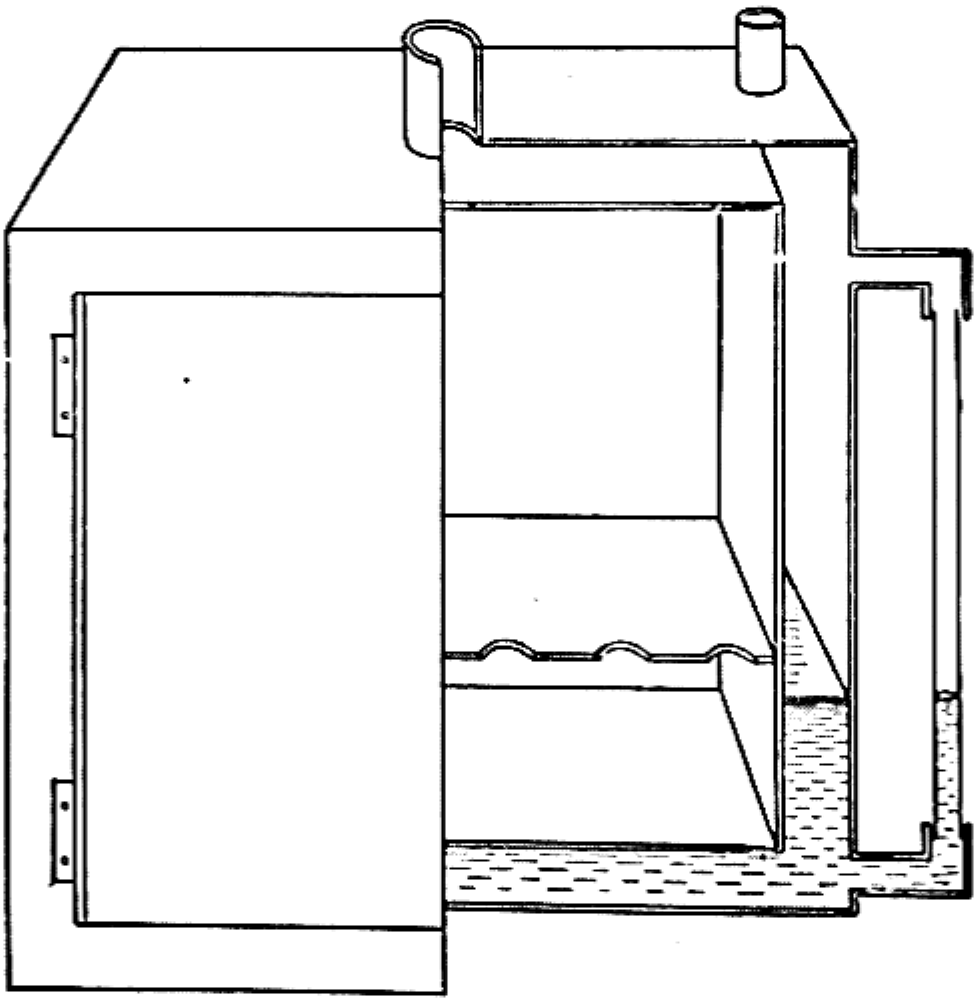


FIG. 9.—Steam oven.

EXPT. 5.—**Effect of heat on wool.** Heat a weighed sample of wool to 130° C. for one hour. Allow to cool and then weigh Note loss of weight and any change in colour, strength, and feel. Expose to air for a day and weigh again. When heated above a certain temperature, wool loses not only its moisture but constitutional water and the fibre is considerably affected.

Plasticity of wool. Wool, when boiled with water, becomes plastic, and, if pressed or stretched and then cooled in this condition, retains the shape given to it. This property is made use of in crabbing and steaming, and has probably a great influence in felting.

EXPT. 6.—**Effect of heat on horn.** Place a horn spoon or spatula in water and boil the water. Take out the spoon, bend it and, while bent, cool it under the tap. The spoon retains the shape given to it. Replace it in the boiling water and notice that the spoon regains its original shape. The substance of the wool fibre is similar to that of horn.

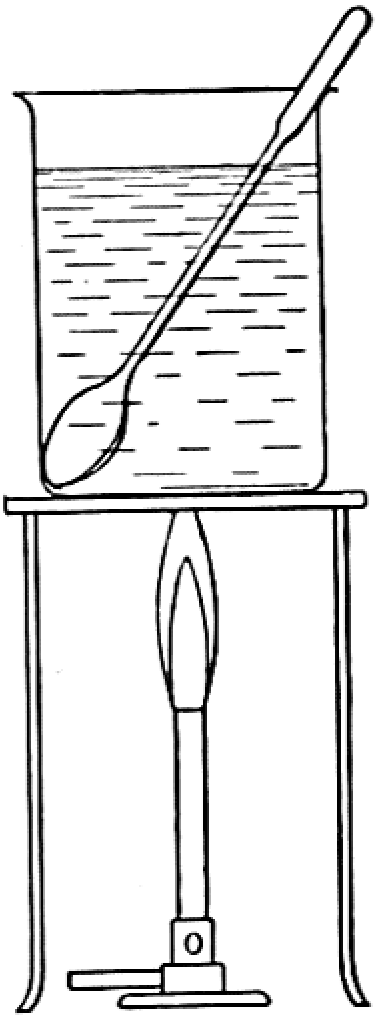


FIG. 10.—Experiment to show the plasticity of horn.

Composition of raw wool. The pure wool fibre is composed of a substance to which the name **keratin** has been given. Keratin is closely allied to the substance of horn, nails, feathers, and hair, and belongs to the class of complex organic bodies known as the proteins. The raw wool contains, in addition to the pure fibre, moisture, wool sweat, wool fat or grease, vegetable substances (burrs, etc.) and earthy matters. The wool may have been washed on the sheep before clipping, but mostly comes into the market in the grease. An analysis of a Lincoln wool gave the following percentage composition :

	Per cent.
Moisture	17·18
Wool fat	6·68
Wool sweat	2·26
Earthy matter, etc.	5·32
Pure wool fibre	68·56

The composition differs considerably with the kind of wool, and may vary between

	Per cent.
Moisture	10 to 24
Wool fat and sweat	10 ,, 47
Dirt	3 ,, 24
Pure wool fibre	30 ,, 80

Wool fat is derived from the fat or sebaceous glands, and is soluble in benzene, petrol, carbon disulphide, ether, carbon tetrachloride, the various chlorethanes (p. 170), and many other organic liquids, but is insoluble in water. Some of its constituents form emulsions with water, all emulsify with alkalis (including soap), and some saponify (p. 121) with alkalis. **Wool sweat** consists of the potassium salts of oleic, stearic, valeric, acetic, hydrochloric, carbonic, phosphoric, and sulphuric acids, together with a nitrogenous substance. These bodies are all soluble in water, but almost insoluble in the organic substances mentioned above. Potassium oleate and potassium stearate are soaps (p. 121). When metallic salts of organic acids are burned, carbonates are generally left. Thus the residue, obtained by evaporating a water solution of wool sweat and a subsequent burning of the product, contains a large percentage of potassium carbonate. An analysis of such a residue gave

	Per cent.
Potassium carbonate - - -	86·77
,, sulphate - - -	6·18
,, chloride - - -	2·84
Oxides of Ca, Si, Al, Fe, etc. -	4·21

The earthy matters present in wool are due to the dust and the soil, and are held in the wool to a large extent owing to the presence of the sweat and grease. When these are removed, as in scouring, the earthy matter is loosened and falls out if the wool is shaken. The burrs, etc., are obtained from the vegetation with which the sheep come in contact, and are removed in some cases by mechanical means and in other cases by chemical treatment (carbonisation).

EXPT. 7.—**Scouring of wool.** Weigh out accurately five 5-gram samples of raw wool. Number each sample by tying a piece of string round it, with knots on a loose end of the string corresponding to the number of the sample.

In four porcelain beakers (500 c.c.) or small dye pots place the following substances :

No. 1 pot.	300 c.c.	water.		
No. 2 ,,	,,	,,	+2 grams of	soda ash.
No. 3 ,,	,,	,,	+2 ,,	soft soap.
No. 4 ,,	,,	,,	+1 gram	soft soap
			+1 ,,	soda ash.

Place the samples numbered 1 to 4 in the corresponding pots, keep the liquids at 50° C., and squeeze the samples occasionally. At the end of half an hour, take out the samples, rinse well in water, and allow to dry.

Place No. 5 sample in a wide-mouthed glass-stoppered bottle containing benzene or other organic solvent, shake for a few minutes, remove (squeezing excess liquor back into the bottle), shake well, and allow to dry.

When all samples have been allowed to dry overnight or longer, weigh and calculate the percentage of impurities removed. Note any difference in colour, felting, feel, etc. Observe the dirt which has been removed.

Enter a portion of each treated sample, and also a sample of the original wool, in a book made for the purpose.

Note.—Many experiments of this type are given in this book, and the entering up of the samples forms an interesting and instructive homework. As special books for the purpose are expensive, the author uses for his classes cards which are scored so that they may be folded and leave a small distance between the folds in order to protect the samples. The cards when filled may be kept either in a cardboard case or between covers. Certain dye firms issued samples of materials illustrating new dyestuffs on such cards and between covers. Enter a brief account of the experiment on one-half of the card, and the samples, together with observations and inferences, on the other, as shown on page 20.

The experiments are given to make the student familiar with the laboratory methods of investigation and to enable him to carry out simple experiments on his own lines. For example, he can try what further loss would be sustained by washing sample No. 5 with water after the benzene treatment, and, by evaporation of the liquid obtained, find what salts he has removed. Also, he may devise processes for estimating the amount of dirt in the wool.

A complete accurate analysis of wool would be beyond the student at the present stage, but a method of analysis is shown below to give an idea of how the composition given on p. 16 could be found.

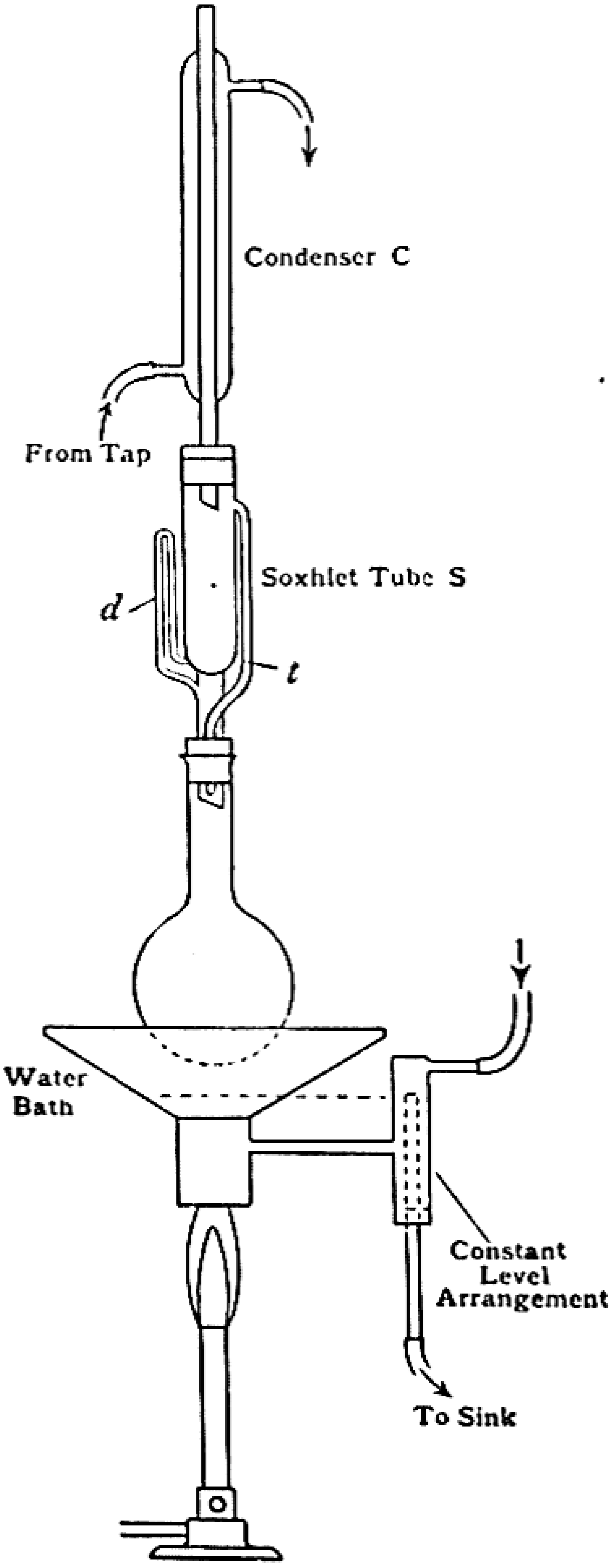


Fig. 11.—Soxhlet Extraction Apparatus.

Expt. 8.—**Analysis of raw wool.** Dry a weighed sample of the wool at 100° C. until the weight is constant. The loss in weight gives the weight of moisture.

Extract the dried sample with ether, and dry and weigh again. The loss of weight gives the wool fat. This extract is best carried out by the use of a Soxhlet apparatus (Fig. 11). Dry ether is placed in the flask which is then heated on the water bath. The ether evaporates, passes up the tube, *t*, into the

THE SCOURING OF WOOL.

Weigh out five 5-gram samples of greasy wool. Number samples 1 to 5.

No. 1. 150 c.c. of water at 50° C. for ½ hr., squeezing occasionally.

No. 2. 150 c.c. of water+2 grms. soda ash at 50° C. for ½ hr., squeezing occasionally.

No. 3. 150 c.c. of water+2 grms. soft soap at 50° C. for ½ hr., squeezing occasionally.

No. 4. 150 c.c. of water+1 grm. soft soap and 1 grm. soda ash at 50° C. for ½ hr., squeezing occasionally.

No. 5. Place in a wide-mouthed stoppered bottle containing benzene, shake for 5 mins. and remove, squeezing the excess of solvent back into the bottle.

Allow all samples to dry in the air to regain their natural amount of moisture and then weigh. Calculate the percentage loss of weight.

Notice the feel of wool, amount of felting, colour, etc.

THE SCOURING OF WOOL.

Samples.	Percentage Loss.	Remarks.
		Original wool.
1.		**Water.** Wool cleaner. No felting.
2.		**Soda ash.** Better than above. Slight felting.
3.		**Soap.** Good scour. Much felting.
4.		**Soap and soda.** Good scour. Much felting.
5.		**Benzene.** No felting. Wool harsh owing to the salts of the wool sweat remaining in the wool.

condenser, C, where the vapour is condensed, and falls back on the weighed sample of dry wool in the Soxhlet tube, S. When the ether in S reaches the level of the top of the siphon tube, *d*, it siphons back into the flask, carrying with it in solution some of the wool fat. The ether again evaporates, condenses, and extracts more wool fat. When finished, the wool may be taken out of the tube, dried and weighed, or the ether may be distilled from the flask and thus leave the fat. If the weight of the flask be known, the weight of the fat can then be obtained by weighing the flask and fat. The ether-extracted wool is now shaken with water and the water extract evaporated to obtain the wool sweat.

The wool now contains, in addition to dirt, certain earthy oleates, so it is treated with alcohol and dilute hydrochloric acid, and then washed and dried. The dry wool is carefully shaken over clean white paper to remove the dirt, any fibres which fall out being collected, and the wool washed with water, dried, and weighed. The difference between the weight of the dry wool and the pure wool + wool fat + wool sweat gives the weight of earthy matters.

Another method is to shake the dry wool with ether and then to pour off the ether into a large separating funnel. Again shake with a little ether and pour this into the same funnel. Shake again with distilled water and run this into the funnel. Shake again with water and squeeze the wool, taking care that all the liquid goes into the funnel. The bottom layer in the funnel is a solution of wool sweat containing in suspension all the dirt. This bottom layer is filtered through a weighed filter paper and the residue washed, dried, and weighed. This gives the amount of dirt.

The wool sweat and grease can be obtained together by scouring a dried weighed sample, when the loss of weight will give the wool fat + sweat + dirt. The wool sweat may be obtained by evaporation to dryness of the filtrate from the water extract after taking care, by washing the ether with water, that all the sweat has been taken from the ether. Evaporation of the ethereal solution will give the wool fat.

Constitution of keratin. The substance of the pure wool fibre, keratin, is composed of five elements: carbon, hydrogen, oxygen, nitrogen, and sulphur. Silk differs by containing no sulphur; and cotton and other vegetable fibres contain neither nitrogen nor sulphur.

	Elements present.
Wool - - -	C, H, O, N, S.
Silk - - -	C, H, O, N.
Cotton - - -	C. H, O.

As previously mentioned, keratin belongs to the proteins, but its composition varies, showing that it is not a single chemical compound. Its average composition is approximately:

Keratin.

	Per cent.
Carbon - - - -	50
Hydrogen - - -	7
Oxygen - - - -	20 to 26
Nitrogen - - -	15 ,, 19
Sulphur - - - -	2 ,, 4

The sulphur varies considerably, and most of it can be removed by solvents without producing an appreciable effect on the quality of the wool. The ash of cleansed wool is less than one per cent. of the weight of the wool.

Expt. 9.—**Carbon in wool.** Burn a small quantity of wool and notice the characteristic smell of burnt feathers. The fibres burn slowly and leave a black bead of carbon.

Expt. 10.—**Elements present in wool.** Heat a small quantity of wool in a dry test-tube. Notice the smell. Hold a piece of filter paper moistened with a solution of a lead salt over the end of the tube; the paper turns brown owing to the formation of lead sulphide (PbS). This shows the presence of sulphur in wool, the gas given off being *hydrogen sulphide* (H_2S).

Now hold a piece of red litmus paper over the tube and it will be turned blue by the *ammonia* (NH_3) given off, and therefore nitrogen is present in the wool.

The residue in the tube, after strongly heating, is carbon, and the liquid which forms on the side of the tube can be shown to be chiefly water (H_2O). Unless carried out with dried wool, this does not show the presence of hydrogen and oxygen in the wool fibre.

The presence of sulphur in the wool may also be shown, as in the following experiment :

EXPT. 11.—**Detection of sulphur in wool.** To a little lead acetate solution in a porcelain dish add a slight excess of caustic soda solution and boil. The solution contains sodium plumbite, and a piece of wool placed in the solution turns brown owing to the formation of lead sulphide (PbS), and thus shows the presence of sulphur in wool.

EXPT. 12.—**Detection of wool in a union of wool and cotton.** Place a small piece of union cloth in the above solution for a few seconds ; then remove and wash it. The positions of the cotton threads, which remain white, are easily seen. Mount a sample of the treated and untreated cloth.

In certain dyeing processes the sulphur in the wool affects the result, and additions are made to prevent the effect (p. 162).

CHEMICAL REACTIONS OF WOOL.

Water. Cold water has practically no action, but prolonged boiling with water decomposes wool to an appreciable extent, ammonia and hydrogen sulphide being given off, and the lustre and strength decreased. A small quantity of wool gelatine passes into solution. Wool boiled with water for a long time shows an increased affinity for colouring matters (see also crabbing and steaming). Steaming at 100° C. rapidly decreases the strength of wool. Water, boiling under pressure, at a temperature of 150° C. readily dissolves wool, but does not materially affect silk. This provides a method for obtaining silk from a silk and wool union.

When wool is dissolved by boiling with water it is said to be hydrolysed, which means that it is decomposed by the addition of the elements of water into two or more substances (compare the effect of boiling fats with caustic soda, p. 121). The products of the hydrolysis are amino-acids.*

Amino-acids are organic acids containing the amino-group $-NH_2$.

Acetic acid has the formula $CH_3 . COOH$; $-COOH$ is the acid group, and the replacement of the hydrogen of this group by a metal results in the formation of a salt thus, $CH_3 . COONa$ is sodium acetate. The other hydrogen atoms can not be replaced by metals and therefore acetic acid is monobasic. They may, however, be replaced by many organic radicles, *e.g.* one hydrogen atom may be replaced by the basic group or radicle $-NH_2$, in which case amino-acetic acid or glycine, $CH_2 . NH_2 . COOH$ is produced. The product is still an acid because of the presence of the $-COOH$ group, and is also basic because of the $-NH_2$ group. Such a substance is therefore capable of uniting with bases and with acids.

Wool may for convenience be considered to have a similar constitution and be represented as

$$W(NH_2).CO.OH.$$

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* When keratin is hydrolysed, the following amino-acids are produced :

	Per cent.
Glycine - - -	4·7
Leucine - - -	7·1
Glutamic acid - -	3·7
Tyrosine - - -	3·2
Proline - - -	3·4
Cystine - - -	8·0

The CO.OH group is an acid group, and the NH_2 group or radicle is basic. W represents the remainder of the wool molecule. (It should be remembered that no formula can be written for wool, and the above formula has only been given to indicate the acidic and basic properties of the wool substance.) The acid group accounts for the action of wool in uniting with basic substances and the basic group for its union with acids.

Acids. The chief acids used in the textile trades are given on pages 151 to 153, and may be classed as follows :

Inorganic : sulphuric, nitric, hydrochloric, sulphurous, and nitrous acids.

Organic : non-volatile—oxalic, tartaric, citric, lactic, tannic, and oleic acids.
volatile—acetic and formic acids.

By boiling with dilute solutions (up to 6 per cent.) of sulphuric acid, wool is practically not affected as regards strength, lustre, etc., but is found to have united with some of the acid, and this acid cannot be completely removed by boiling water. The wool so treated has acquired the property of uniting with acid colours (Expt. 14), but its affinity for basic colours has decreased. Sulphuric acid of 30 per cent. strength quickly hydrolyses the fibre and dissolves it. A few minutes treatment with cold concentrated sulphuric acid causes wool to lose its affinity for acid colours and to increase its affinity for basic colours.

EXPT. 13.—**Effect of sulphuric acid on wool.** Try the effect of cold and hot solutions of sulphuric acid on small quantities of woollen yarn in test-tubes.

Dilute hydrochloric acid behaves similarly to dilute sulphuric acid, but very little acid remains combined with the wool after a washing with boiling water.

Hot dilute nitric acid causes wool to turn yellow, the formation of the yellow compound (xanthoproteic acid) being more rapid as the strength of the acid is increased. Weak solutions (3°-4° Tw.) of nitric acid may be used for stripping shoddy, *i.e.* removing the colour.

Very little tannic acid is absorbed by wool from cold solutions of the acid, but when treated with hot strong solutions the fibre becomes harsh and its affinity for dyestuffs is decreased. The tannic acid may be fixed on the fibre by treatment with metallic salts, such as tartar emetic, stannous chloride, etc.

Chromic acid is absorbed from dilute solutions in a similar manner to sulphuric acid.

Nitrous acid diazotises wool (p. 182), and the product may be dyed by developing, as in the dyeing of cotton with diazo-colours.

Organic acids, with the exception of tannic acid, are readily absorbed by wool and, like sulphuric acid, give the wool an affinity for acid dyes.

EXPT. 14.—**The effect of acids on wool.** Wet out by boiling with water four 5-gram hanks of wool. Number the hanks (conveniently done by knotted string), then place them in the following liquids contained in beakers or dye pots as before :

Nos. 1 and 2 hanks in 300 c.c. of water.
,, 3 ,, 4 ,, ,, ,, ,, +3 c.c. conc. sulphuric acid.

Give all hanks equal treatment by raising to the boiling point and boiling 20 minutes. Squeeze out hanks 1 and 3 and allow them to dry. Compare their strength, lustre, etc. Compare them with cotton similarly treated (Expt. 35). Now wash No. 2 hank well, and then wash No. 4. Take care that No. 2 hank is not touched with acid. All pots must be clean or wrong results will be obtained. Place hanks Nos. 2 and 4 in separate pots, each containing 150 c.c. of water + 0·05 gram

EFFECT OF ACIDS ON WOOL.

Number and wet out four 5-grm. hanks of wool.

No. 1 and 2 hanks in 300 c.c. water.

No. 3 and 4 hanks in 300 c.c. water plus 3 c.c. conc. sulphuric acid.

Raise to boiling point and boil 20 mins. Squeeze out hanks Nos. 1 and 3 and allow to dry. Compare *strength*, *lustre*, etc. Rinse well hank No. 2 and then rinse No. 4. Place these in separate pots each containing:

150 c.c. water plus 1 per cent. of acid Magenta.

Raise to boiling point; boil 20 mins. Rinse well and dry.

EFFECT OF ACIDS ON WOOL.

Samples.	Remarks.
	Original wool.
No. 1.	No noticeable effect on strength, lustre or feel.
No. 3.	Do.
No. 2.	Not dyed.
No. 4.	Dyed.

of acid magenta (or other acid dye). Raise to boiling point and boil each for 20 minutes. Take out the hanks, rinse them well and dry them. The sulphuric acid treatment will have caused the wool to unite with the dye. Mount samples of all four hanks as in previous experiments. Similar experiments may be arranged with other acids and other strengths.

Note.—In dyeing it is customary to express the amount of dyestuff to be used as a percentage of the weight of the material, so that instead of giving the weight of acid magenta as 0·05 of a gram it could have been expressed as 1 per cent., thus :

150 c.c. water + 1 per cent. of acid magenta,
0·05 gram being 1 per cent. of 5 grams (weight of one hank).

Alkalis. Sodium hydroxide (caustic soda, NaHO) and potassium hydroxide (caustic potash, KHO) are known as *caustic* alkalis. Sodium carbonate (soda ash, Na_2CO_3), potassium carbonate (pearl ash, K_2CO_3), and ammonia (NH_3) are known as *mild* alkalis. Solutions of many other substances, such as sodium silicate (water glass), borax, soap, sodium phosphate, and ammonium carbonate, have an alkaline reaction and may be used as mild alkalis.

Hot weak solutions of alkalis have a deleterious effect on wool. Hot solutions of the caustic alkalis have a much greater effect than solutions of equivalent strengths of the mild alkalis. Even hot soap solutions are detrimental, and it is therefore necessary when treating wool with alkalis (*e.g.* in scouring) to keep the temperature below 120° F. (roughly 50° C.) and to see that the soap is free from alkalis, particularly caustic alkalis.

EXPT. 15.—**Lanuginic acid.** Boil a little wool with dilute caustic soda solution until dissolved, and then carefully acidify with hydrochloric acid ; a white precipitate of *lanuginic acid* is obtained. Wool dissolves in hot solutions of barium hydroxide, and the barium may be precipitated as barium carbonate by passing carbon dioxide through the solution. If the solution be filtered from the barium carbonate, and lead acetate added to the filtrate, a precipitate of lead lanuginate is obtained. From this lanuginic acid may be obtained by decomposition with hydrogen sulphide.

Lanuginic acid is soluble in water, and the solution precipitates acid colours in acid solutions and basic colours in neutral solutions. It gives precipitates with tannic acid, bichrome, many metallic salts, and in general behaves like keratin. Its composition is different from wool, and it is not a single substance.

Cold caustic alkalis have a striking effect on wool. Yarn with a breaking strain of 610 grains was immersed in cold caustic soda solution for 10 minutes. (A longer immersion causes deterioration.) The yarn was washed well in water containing a little acetic acid to remove the alkali, and then air-dried and tested. The following results were obtained.

Strength of solution. °Tw	Breaking strain grains.
5·8	570
15·0	430
25·0	180
32·4	95
52·6	335
76·6	770
82·4	875

Above this weakening again occurs.

It is found that a considerable amount of caustic soda has been absorbed by the wool, that most of the sulphur has been removed, and that the affinity of the wool for all classes of dyestuffs has been increased.

Ammonia and ammonium carbonate are very weak alkalis, and have practically no effect on wool.

Expt. 16.—**The effect of alkalis on wool.** Number four wool hanks and treat as below:

No. 1 hank in 150 c.c. of water.
,, 2 ,, ,, ,, + 2½ grms. of caustic soda.
,, 3 ,, ,, ,, + 2½ grms. of soda ash.
,, 4 ,, ,, ,, + 2½ grms. of ammonium carbonate.

Raise each bath to boiling point, and boil for 20 minutes. Dry the hanks and compare them for strength, feel, colour, etc. No. 2 hank will have dissolved; No. 3 hank will be weak, harsh, and yellow; and No. 4 hank almost unaffected. Mount samples as before, leaving a space for No. 2.

The above experiment provides a method for determining the percentage of cotton in a union of wool and cotton, the latter being only slightly affected by alkalis.

Expt. 17.—**Analysis of a union cloth (cotton and wool).** Weigh out exactly 5 grams of the union, place it in 150 c.c. of water containing 2½ grams of caustic soda, and boil the solution till the wool has dissolved. Take out the cotton, wash it with cold water, then in water containing a little acetic acid, then again in water, and allow it to dry in the air for a day or longer. Weigh the cotton, add 5 per cent. of the weight of the cotton to compensate for loss during the treatment, and calculate the percentage of cotton in the union. Mount a convenient size of the union, say 1 gram, and underneath it mount the quantity of cotton which would be obtained from it in the experiment.

Salts. Solutions of neutral salts, such as Glauber's salt, $Na_2SO_4 . 10H_2O$, and common salt, $NaCl$, have no action on wool though it is said that prolonged boiling impairs the lustre. Solutions of magnesium chloride, $MgCl_2$, and aluminium chloride, $AlCl_3$, become acid when boiled with wool. Salts which are themselves acid in reaction are readily dissociated by the wool, the acid portion of the salt uniting with the basic radicles of the wool and the basic portion of the salt with the acid radicles. Thus aluminium sulphate is split up and alumina (or a basic aluminium sulphate) fixed on the fibre. Part of the acid is also taken up.

$$Al_2(SO_4)_3 + 3H_2O = \underset{\text{alumina}}{Al_2O_3} + 3H_2SO_4.$$

This fixing of metallic oxides or basic salts on the fibre is known as **mordanting,** but the term also includes the fixation on a fibre of any substance, *e.g.* tannic acid, which is capable of uniting with colouring matters. The quality of the mordanting depends upon the particular salt of the metal used. For mordanting with aluminium, aluminium tartrate is especially good, but the oxalate is only slightly inferior. Both these are to be preferred to the sulphate, which in its turn is better than alum. The tartrate may be replaced by a mixture of the sulphate and tartar (potassium hydrogen tartrate). The tartar used in this way is known as an **assistant.** An assistant is a substance added to the dyebath during mordanting or dyeing to improve the dyeing or to produce some special effect.

When wool is mordanted with ferrous sulphate (copperas), ferrous oxide is taken up by the fibre. With potassium dichromate (bichrome) the wool unites with a yellow substance which is probably chromium chromate. Here the wool has acted as a mild reducing agent and the wool is yellow chromed. In the presence of certain assistants, as oxalic, formic, and lactic acids, the reduction is greater and the wool is green chromed.

Wool mordanted with metallic salts is capable of uniting with colouring matters, *e.g.* alizarine, haematin, etc., to form fast dyes.

Mordanting. The student may carry out one or more of the following experiments on mordanting. The first of these shows the effect of the quantity of mordant on the dyed product, the second the effect of assistants, and the third the effect of different mordants on the colour.

EXPT. 18.—**Effect of quantity of mordant.** Number and wet out five 5-gram hanks of wool. Mordant the hanks in the following solutions by bringing the solutions slowly to the boiling point (half an hour) and boiling them for three-quarters of an hour. (The times are shorter than in practice.)

No. 1 hank in 150 c.c. water.
,, 2 ,, ,, ,, + $\frac{1}{2}$ per cent. of bichrome.
,, 3 ,, ,, ,, + 1 ,, ,, ,,
,, 4 ,, ,, ,, + 3 ,, ,, ,,
,, 5 ,, ,, ,, + 6 ,, ,, ,,

Rinse the hanks well and take a small sample of each for mounting. Without drying, dye the remainder of each hank in separate pots, each containing

150 c.c. water + 1 % alizarine + 1 % acetic acid.

Raise the baths slowly to the boil and boil for three-quarters of an hour. Rinse and dry the hanks. Compare their shades. It will be found that much of the mordant is wasted if more than a certain amount be used.

Note.—For convenience and quickness in measuring the small quantities of substances used in the above and similar experiments, it is useful to make up standard solutions (or mixtures where the substance does not dissolve) of such substances of a strength, say 1 in 20, in which case 1 c.c. of the solution will contain 0·05 of a gram, *i.e.* 1 per cent. on 5 grams of material. The quantities required may then be measured out by means of a burette or by a 10 c.c. pipette graduated in tenths of a c.c.

EXPT. 19.—**Logwood.** Repeat the mordanting, as in the previous experiment, and dye with logwood or haematin (see below). Or, in the previous experiment, after taking samples of the mordanted wool, cut the remainders of the hanks into two equal parts, and dye one-half of each with alizarine and the other with logwood. Remember in this case that the percentage of dye taken must be calculated on 2½ grams. Note the effect of **overchroming.**

Overchroming. The colouring principle in logwood is called haematoxylin, which rapidly oxidises on exposure to air forming haematin, the true colouring matter. This oxidation is carried out by exposing the chipped or rasped logwood to the air, and must be carefully carried out to avoid over-oxidation. Haematin is now sold as a dark-brown crystalline substance, and has almost wholly replaced the chipped or rasped logwood in dyeing. Haematin is liable to destruction by oxidation, and in the last experiment the student may have noticed that the mordanted wool was yellow. The yellow substance is a chromate, and chromates are oxidising agents. When wool, thus mordanted, is dyed with haematin, some of the haematin is oxidised, and, if the wool has too great an amount of mordant, *i.e.* is overchromed, it will be found impossible to get a good colour.

If an addition be made to the mordanting bath, so that instead of the yellow chromate, green chromium oxide is deposited, there is no danger of oxidation, and, in addition, the colour is brighter and faster to light. Formic and lactic acids may be used for this purpose, or the wool may be mordanted with bichrome as before, and the chromate reduced to the green oxide by immersing the mordanted wool for a few minutes in a weak solution of sodium bisulphite. Sulphuric acid when used with bichrome causes a greater amount of chromium to be fixed on the fibre than with bichrome alone, but causes a slight deterioration of the wool, owing to the powerful oxidising action of the liberated chromic acid.

$$\overset{\text{Bichrome}}{K_2Cr_2O_7} \overset{+}{+} \overset{\text{Sulphuric acid}}{H_2SO_4} + H_2O \overset{\rightarrow}{=} K_2SO_4 + \overset{\text{Chromic acid}}{2H_2CrO_4}.$$

Many experiments can be tried, using bichrome with different assistants and different amounts of such assistants, and the following experiment will illustrate the effect of such additions :

Expt. 20.—**Effect of assistants in mordanting.** Number and mordant six 5-gram hanks as follows :

No. 1 hank in 150 c.c. water.
,, 2 ,, ,, ,, +3 % bichrome
+2 % sulphuric acid.
,, 3 ,, ,, ,, +3 % bichrome
+2½ % formic acid.
,, 4 ,, ,, ,, +3 % bichrome +2½ % tartar.
,, 5 ,, ,, ,, +3 % bichrome
+2½ % oxalic acid.
,, 6 ,, ,, ,, +3% bichrome +1% sulphuric acid +4 % lactic acid.

Raise to boiling point in half an hour and boil for three-quarters of an hour. Note the colours of the mordanted wools and mount a small sample of each after rinsing. Note also the exhaustion of the baths. Dye the remainder of each hank in one of the following :

Place each hank in 150 c.c. water + 10 % logwood chips (or 1 % haematin)
or ,, ,, ,, ,, +1 % alizarine + 1 % acetic acid.
or ,, ,, ,, ,, +1 % alizarine green, alizarine cyanine G, anthracene blue, W.B., etc.

Rinse the hanks, dry them, and compare their shades. The hanks may be divided after mordanting and used for several colours.

Polygenetic dyes. Haematin, alizarine, and many other colouring matters will not dye wool unless the latter has been suitably mordanted ; and the colour produced on the mordanted wool depends upon the kind of mordant used. Tin and aluminium mordants give light shades, iron and copper dark shades, and bichrome intermediate. Thus with alizarine, aluminium gives a red ; bichrome, a claret ;

and iron, a brown. Such colouring matters are called polygenetic; and dyes or coloured substances, such as magenta, malachite green, etc., which only give one colour, may be termed monogenetic. The following experiment illustrates the effect of the mordant on the colour:

Expt. 21.—**Effect of different mordants on the colour.** Number and mordant five 5-gram hanks as follows:

No. 1 in 150 c.c. water + 4 % tin salt + 2 % oxalic acid.
" 2 " " + 5 % alum + 3 % tartar.
" 3 " " + 3 % bichrome + 2½ % tartar.
" 4 " " + 6 % copperas + 12 % tartar.
" 5 " " + 10 % blue vitriol + 2 % sulphuric acid.

Raise to boiling point in half an hour and boil for three-quarters of an hour. Rinse the hanks and note differences in colour of the mordanted wools. Mount a sample of each hank, and dye the remainders with alizarine, as in Expt. 18. Note the bright colours with tin and aluminium, and the dull shades with iron and copper. Further particulars about mordants and assistants will be found in books on dyeing.

Chlorine and hypochlorites. Chlorine is a greenish-yellow gas with a pungent suffocating smell. It dissolves in water, forming a greenish-yellow solution known as chlorine water. When required in textile work, it is obtained by the action of acids on bleaching powder or electrolytic bleach. (See under cotton bleaching, p. 91, for further information about these substances.)

Perfectly dry chlorine has no action on dry wool, but moist chlorine gas rapidly attacks wool and converts it to a pulpy substance. When treated with a weak solution of chlorine or a hypochlorite, the wool acquires the following properties:

(*a*) *Increased transparency.*

(*b*) *Increased gloss and scroop.* This increased gloss has been the subject of many patents, but the soft feel, so prized in wool, is lost and the processes are, therefore, not used.

(*c*) *Increased affinity for colouring matters.* This effect is made use of in several ways: (1) a material, made by weaving chlorinated yarn into a design with unchlorinated yarn, can be dyed in a single bath with the production of two depths of shade; (2) in the dyeing of skin rugs, boiling with water would damage the skin, but by chlorinating the rug the dyeing may be carried out at a much lower temperature without decrease in penetration of the dye; (3) to secure penetration of the dye when printing delaines.

(*d*) *Loss of felting property.* The chlorine seems to soften and round off the projecting edges of the scales of the fibres and thus diminish the interlocking of the fibres. Wool fabrics may be chlorinated to render them unshrinkable. If chlorinated and unchlorinated yarns be woven together and the fabric milled, a crepon effect can be obtained owing to the felting and consequent shrinking of the unchlorinated yarn.

EXPT. 22.—**Effect of bleaching powder on wool.** Wet out two 5-gram wool hanks. Prepare a solution of bleaching powder, 2° Tw., as follows. Grind about 3 grams of bleaching powder into a paste with a little water. Add more water till it becomes a cream, and then dilute and filter through a piece of fine cotton cloth into a tall jar. Dilute until a hydrometer shows 2° Tw.

Place the solution in a beaker and enter one of the hanks. Allow the hank to stand in the solution for half an hour, and then transfer it to a solution of hydrochloric acid (about 2° Tw.) for a few minutes. Note the smell of the liberated chlorine

$$\overset{\text{Bleaching powder + acid}}{CaOCl_2 + 2HCl} \overset{\rightarrow}{=} CaCl_2 + H_2O + \overset{\text{Chlorine}}{Cl_2}.$$

Take the hank out of the acid and rinse it well. Place the chlorinated hank and the untreated hank in separate pots, each containing

150 c.c. water + 1 % patent blue superior (M.L.B.) or other acid dye.

Raise to boiling point and boil for 20 minutes. Rinse well, dry half of each hank, and compare feel, purity and depth of shade, etc. The chlorinated hank is harsh.

Take the other halves and rub each in warm water in which are dissolved 1 gram of soap and 1 gram of soda ash per 200 c.c. Give the same treatment to each and note any difference in felting property.

Dyes. Wool has a strong affinity for colouring matters, and it dyes direct with acid, basic, and salt dyes. With mordant dyes the wool is first mordanted, as in Expts. 20 and 21. Indigo, being insoluble, is reduced to indigo white, which is soluble in a weak alkaline liquor, and from the solution formed, the wool takes up the indigo white. On exposure to the air, the indigo white is oxidised to indigo. Bearing in mind the action of alkalis on wool, the alkali used should be very weak, and slaked lime or, more commonly, ammonia is employed.

EXPT. 23.—**Behaviour of wool towards dyes.** Number and wet out six 5-gram hanks of wool. Dye as below.

1. *Acid dyes.* Prepare the following bath :

150 c.c. water + 10 % Glauber's salt + 4½ % sulphuric acid + 1 % acid magenta or other acid dye.

Place No. 1 hank in the bath, raise to boiling point and boil for three-quarters of an hour or until the bath is exhausted. In all experiments the material must be stirred to get even results.

2. *Salt dyes* (Substantive dyes or D.C.D.'s). Prepare a bath of

150 c.c. water + 10 % Glauber's salt + 1 % acetic acid + 1 % benzopurpurin or other salt dye.

Place No. 2 hank in the bath, raise to boiling point and boil for three-quarters of an hour.

3. *Basic dyes.* Prepare a bath containing

150 c.c. water + 1 % acetic acid + 1 % methyl violet or other basic dye.

Place No. 3 hank in the bath, raise to boiling point and boil for three-quarters of an hour.

4. *Mordant dyes.* Mordant hank No. 4, as in Expt. 20 No. 3, and dye as there mentioned with alizarine. Into a similar dye bath place also an unmordanted hank, No. 5. Take half of each hank and wash well in 150 c.c. of water + $\frac{1}{2}$ gram of soap at 50° C. Rinse and dry the samples. Mount samples of all four specimens.

5. *Vat dyes* (indigo). Prepare a vat as follows :

300 c.c. water + 2 c.c. strong ammonia + $\frac{1}{2}$ gram of hydrosulphite.

Heat the vat to 50° C. and add 1 gram of indigo paste (20 per cent.). Stir the vat well and allow it to stand for 10 minutes. The colour of the solution, as seen by lifting some of the liquid up in a glass tube, should be greenish yellow. Place No. 6 hank in the solution, allow it to remain 30 minutes, take it out, squeeze it, and allow it to oxidise in the air. Wash the hank well with soap and water. Six separate dips of 5 minutes each may also be tried.

Wool is liable to mildew if left in a warm moist condition, and especially in the presence of a little alkali

QUESTIONS III.

1. What is meant by conditioning ? How would you estimate the percentage of moisture and oil in a sample of worsted yarn ?

2. What is the composition of the purified wool fibre ? How would you show the presence of sulphur and nitrogen in wool ?

3. What is the effect of cold solutions of caustic soda on the wool fibre ?

4. What do you mean by a mordant ? Give some of the common mordants used for wool.

5. How would you mordant wool with bichrome, and what is the effect of overchroming when dyeing with logwood (or haematin) ?

6. What effects are produced in wool by the action of chlorine or hypochlorites ?

7. Give the action of (*a*) solutions of alkalis, (*b*) solutions of acids of varying strengths and at different temperatures on wool.

CHAPTER IV

WOOL SCOURING, ETC.

Scouring of raw wool. After sorting the fleece according to length of staple, fineness, soundness, and colour, the wool is scoured. Wool scouring may be carried out in three different ways:

A. With alkaline detergents.

B. By steeping in warm water followed by alkaline detergents.

C. With organic solvents.

The detergents used being alkaline, it is evidently important that the strength of the alkali and the temperature of scouring should not be overlooked.

Detergents. A detergent is a cleansing agent. Soaps, ammonia, ammonium carbonate, stale urine (valuable because of its ammonia), and borax have very little action on the fibre and are safe to use as detergents. The soap must be of good quality. Cheap soaps may contain free alkali, sodium silicate, resin, China clay, etc.; and soap for scouring should be free from these. The water used in scouring must be free from dissolved solids, otherwise insoluble soaps ("lime" soaps) may be formed, and these would cause trouble in dyeing. There would also be a considerable waste of soap. Lime soaps are difficult to remove, and it is far cheaper to soften the water before using (pp. 127-140).

A. **Scouring with alkaline detergents.** This method is in common use in this country. The chief scouring agents are :

1. **Soap.** An olive oil soap is best, but is seldom used. Soft soaps have a greater emulsifying power than the curd soaps, but they are expensive and liable to contain free caustic potash. The water present in a good curd soap should not exceed 30 per cent. and the free alkali should be less than 1 per cent. In a soft soap the water should not exceed 45 per cent. and the free alkali 1·5 per cent.

2. **Sodium carbonate** (soda ash) or, in rare cases, **potassium carbonate** (pearl ash). These should be free from caustic alkali.

The proportions of soap and soda used in scouring depend upon the kind and quality of the wool, and in no case should the temperature be allowed to rise above 50° C. With too high a temperature the alkali attacks the fibre, causing a loss of elasticity and producing a yellow colour.

Scouring machines. Modern scouring machines are made with several definite objects in view, and if the reader will keep these in mind, he will readily understand the use of the separate parts of the machine. The chief objects are (*a*) economy in chemicals and steam, (*b*) minimum labour, (*c*) minimum movement of the wool in order to prevent felting, (*d*) an even degree of cleanliness of the washed wool.

Petrie's machine. A diagram, Fig. 12, is given of a machine made by Petrie of Rochdale embodying these principles. In this machine the scouring liquor is maintained in good condition by an automatic device which periodically removes grease and dirt and replenishes the bowl with clean liquor. No time is wasted, therefore, by

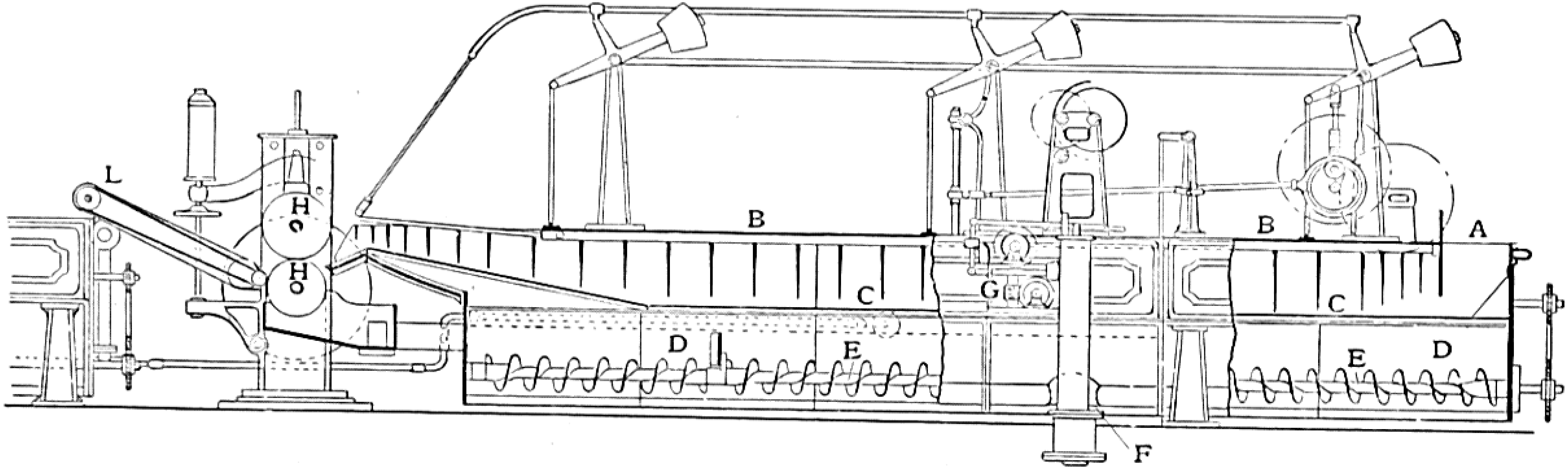


FIG. 12.—Diagram of Petrie's self-cleaning wool washing machine. Harrow type. Bowl 21 ft. 0 in. long, 3 ft. 0 in. wide.

A. Entrance for the raw wool.
B. Harrow to carry the wool through the liquor.
C. Perforated plates of the upper bowl.
D. Semicircular trough into which the dirt falls from the upper bowl.
E. Conveyor with right and left-hand drive to carry the dirt to a central hopper.
F. Outlet valve from central hopper. The valve is opened and the dirt removed at intervals. The valve is controlled by the timing mechanism, G.
H. Squeeze rollers to squeeze the wool and return the liquor to the bowl.
L. Apron to convey the wool to the next bowl.

the changing of the liquors, and there is a consequent saving in soap, steam, water, and labour. Further, the liquor being of a constant condition, all the wool is treated to the same extent and an even scouring is produced. The movement of the wool through the liquor is brought about by swing rakes or harrows. The harrow causes less agitation than the swing rake, and is therefore more suitable for fine wools, and the swing rake for coarse wools.

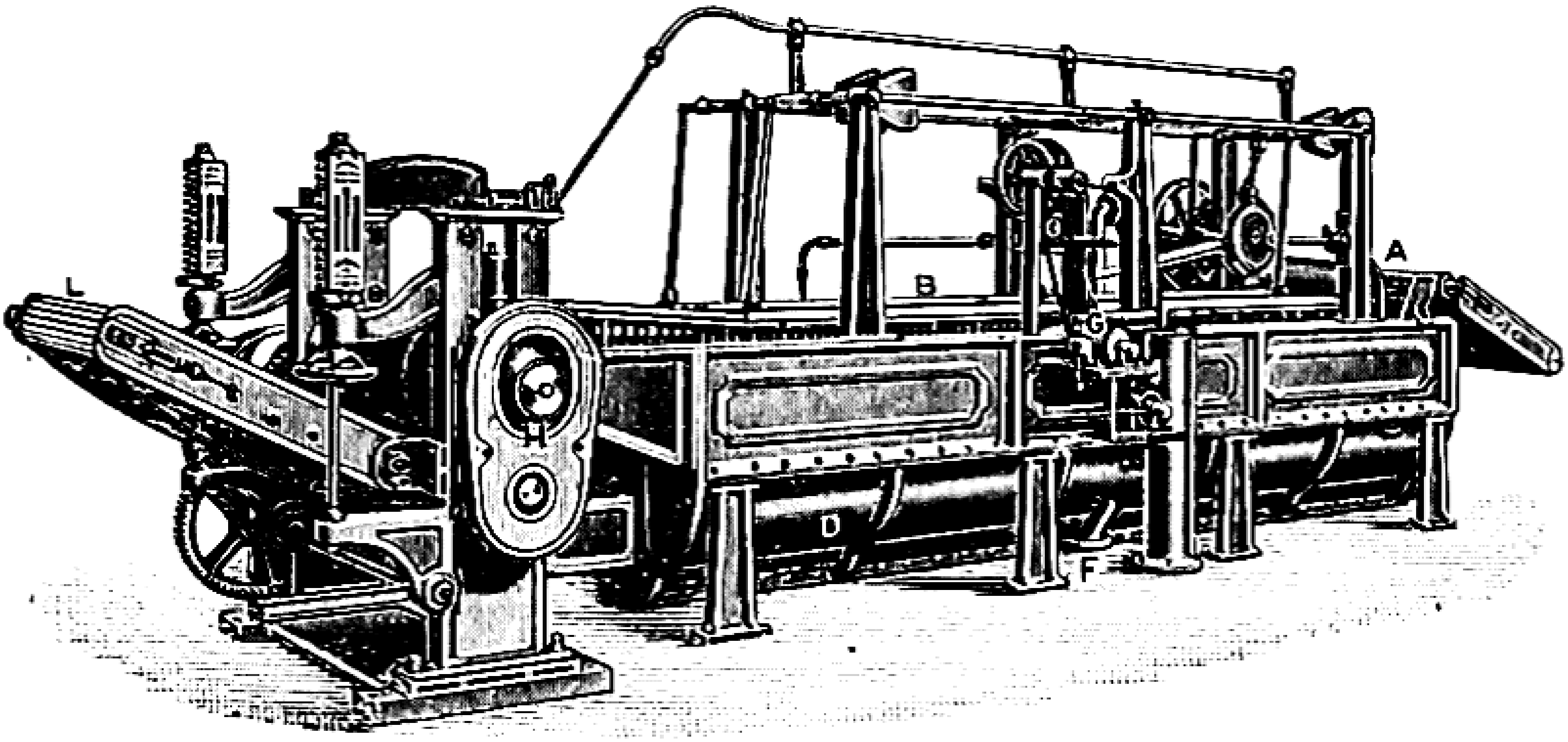


Fig. 13.—Petrie's automatically self-cleaning wool washing machine.

Scouring machines generally contain three or four bowls which vary in capacity and in the strength of solution contained in them. An example of the detergents and the quantities in each bowl for scouring a merino wool is taken from the *Wool Year Book* and given on the next page.

Treatment of waste scouring liquors. The waste scouring liquors from this process are emptied into **sud** or **seek tanks.** The tanks are generally built of brick and lined inside with cement or are built of large flagstones. Sulphuric acid (or nitre cake) is added to the liquor and decomposes (**cracks**) the soaps used in the scouring, and also the soaps of the wool sweat. The alkali used in scouring is neutralised, and the liberated fats and oils rise to the surface. The liquid is then run through a filter of cinders covered with sawdust. The filtrate which contains the valuable potash salts of the wool sweat is run to waste, and the residue of fats, mixed with loose fibres, is wrapped in canvas. The fats and oils are recovered by heating and squeezing the bags, and the substance left is sometimes used as a manure (sud manure), but is frequently burned. The composition of the recovered fat varies considerably and may contain from 50 to 85 per cent. of saponifiable matter. It is sometimes used in the manufacture of inferior soaps, but may be distilled with superheated steam when two products are obtained—one a liquid called " oleine "; and the other a solid, " stearine." The oleine is used as a lubricant in spinning and the stearine in candle manufacture.

CONSTITUTION OF WASH BOWLS

(Quantities required per day)

(*a*) Twenty packs (4800 lb.) merino wool of 50 per cent. estimated yield.

	1st Bowl.	2nd Bowl.	3rd Bowl.	4th Bowl.
Length of bowl ft.	30	24	18	13
Capacity - - gals.	1800	1500	1000	750
Temperature - °F.	120	115	110	105
Soap (potash) - lbs.	125	65	40	10
Alkali (K_2CO_3) - lbs.	35	5	—	—
Immersion -mins.	3	—	—	—

Agitation: Minimum—just sufficient to float wool through the machine.

B. **Continental method of scouring.** The second method of scouring is employed on the continent, and the preliminary steeping removes the potash salts of the wool sweat, forming a solution from which these salts may be recovered. At the same time a certain amount of the dirt is released and falls out, so that the subsequent soap bath lasts much longer. The disadvantages are that there are two operations instead of one and that slightly more soap is required in the second operation owing to the removal of the natural soaps by the first. The potash salts recovered are valuable, but unless waste heat is available for evaporation the recovery is unprofitable. The residue after evaporation is burned, and a solid, rich in potassium carbonate (p. 17), is obtained.

C. **The solvent process.** This process does not make much headway though, theoretically, it is the best. It is said to take too much of the grease from the wool, making it less easily worked in the after processes, but the workers of the process guarantee to leave any required amount of fat in the scoured wool. The wool is placed in large cylinders, and a suitable solvent (p. 170) is forced through them. After the wool has been sufficiently treated, the solvent is forced out and the wool is dried by passing warm air through the cylinders. The vapour of the solvent thus carried out is condensed and recovered. When the solvent has collected in itself sufficient grease, it is distilled and used again. The fat recovered by the distillation is put to various uses, some of it being worked up with water into a stiff cream known as *lanoline*. There is no felting of the wool in the solvent process.

The chief difficulty in this method of scouring is to prevent loss of the expensive solvent. Most of the solvents mentioned on p. 17 are inflammable. Carbon tetrachloride, CCl_4 (B.Pt. 74° C.), is sold as antiflammin and is not inflammable, but is expensive and attacks iron. Tetrachlorethane, $CHCl_2 . CHCl_2$, and pentachlorethane, $CCl_3 . CHCl_2$, which are derivatives of ethane, C_2H_6, are non-inflammable and may be used. These and similar solvents are frequently used in piece scouring (see later). About one pint is added to the liquor used for 250 lbs. of cloth.

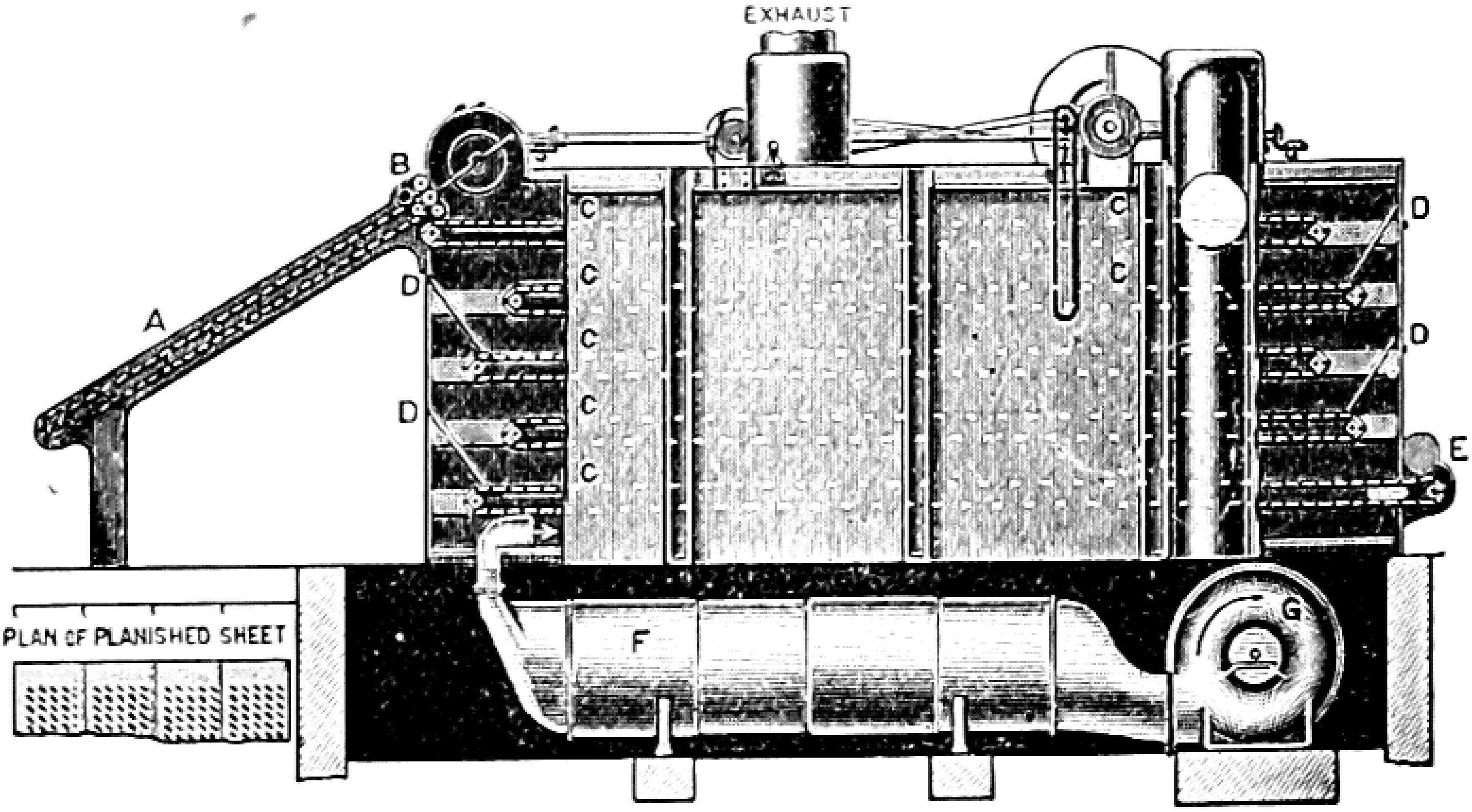


FIG. 14.—Wool drying machine (Whiteley's, Huddersfield).

A. Feed lattice.
B. Feed rollers.
C.C. Creeper wool carriers (planished sheets).
D.D. Guide plates.
E. Delivery rollers.
F. Heater.
G. Fan which drives air through the heater and thus upwards through the wool.

Wool drying. After leaving the scouring bowls, long and medium wools are dried to remove some of the water. The drying is carried out by hot air, and it should be remembered that it is not necessary to drive out all the water, but that a uniform drying should be aimed at. The wool may be laid on wire-netting and the air blast sent through, but to save cost of labour it is generally carried by the hot blast and/or some form of conveyer (rollers, apron, etc.) through a special drying machine (Fig. 14). In some cases the wool is dried and, at the same time, conveyed to another floor of part of the building by being swept along a wide tube by the current of hot air. This may cause a little matting of the fibres owing to the whirling motion imparted, but saves much labour. The wool must not be dried at too high a temperature.

Oils used in spinning. The wool is now ready for conversion into yarn, and, during the process, is oiled to give a free movement of the fibres and prevent felting. The choice of oil is important, because, in addition to cost, one must take into account the removal of the oil from the yarn or piece before dyeing and the liability of the oil to spontaneous combustion. Olive oil is best, but is expensive. Nut oil, lard oil, and other vegetable and animal oils may be used. All these oils readily emulsify with soap, and are thus easily removed. Oleic acid (p. 118) when pure is also extremely satisfactory, and also readily saponifies. Oleine (p. 44) is used, but is not as good as those already mentioned. The mineral oils (shale oil, petroleum, etc.) are hydrocarbons, *i.e.* compounds of hydrogen and carbon. The heavier mineral oils may be used for lubricating the wool, but they neither emulsify nor saponify, and are difficult to remove. If used at all, they should be mixed with a very large proportion of animal or vegetable oil.

Wool creams. For better distribution and more economical use, the oil may be made into an emulsion (see wool creams, p. 124). Such emulsions are readily made by adding pure water to the oil and then sufficient weak alkali—ammonia for preference—until the mixture emulsifies. The proportions of oil and water may be varied, and trials made to secure the best mixture. Ready-made emulsions often contain inferior oils and should only be purchased under guarantee.

Yarn scouring. Some yarns, *e.g.* carpet yarns, are dyed without scouring, but the majority are scoured. Yarn scouring is frequently done by hand, but many types of machines for yarn scouring are on the market. Petrie's machine for hank washing is designed similarly to that for loose wool. The yarn is carried successively through a series of wash bowls and squeezing presses, each bowl being fitted with two endless brattices which carry the hanks between them through the liquor and deliver them to the squeezing rollers.

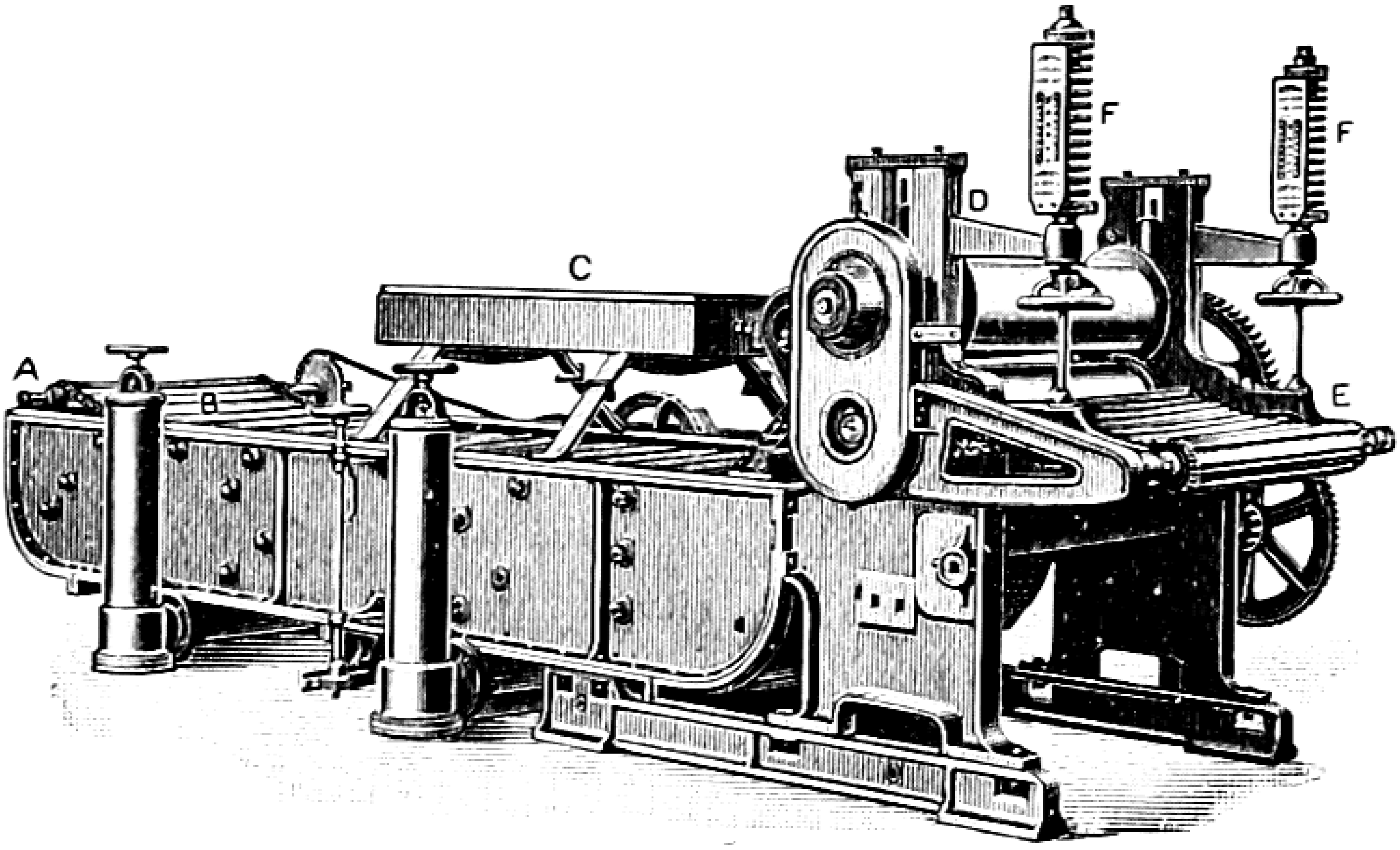


FIG. 15.—Petrie's hank washing machine.

A.	Feed end of bowl.
B.	Brattices between which the hanks are carried through the liquor and to the squeezing rollers.
C.	Shower cistern into which liquor is pumped from the bowl. The liquor falls on the hanks and soaks them before they enter the liquor in the bowl.
D.	Squeezing rollers.
E.	Delivery end with conveyor for carrying the hanks to another bowl.
F.F.	Springs for producing pressure between the rollers.

The arrangement of the brattices is shown in Fig. 16. The hanks travel in the direction indicated by the arrows.

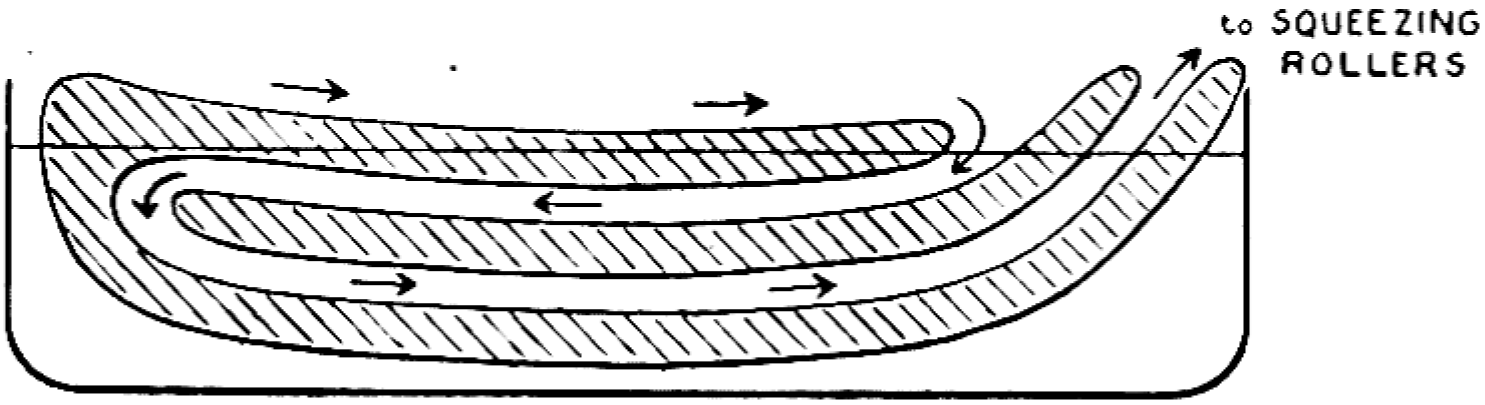


FIG. 16.—Diagram showing the path of the hanks through the liquor.

Piece scouring. Pieces are generally scoured in a "dolly" in which the cloth passes in rope form between a pair of heavy rollers, R, R (Fig. 17), the lower one of which dips into the warm scouring liquor and conveys it to the cloth. The liquor (soap, soda, and, if necessary, a small quantity of an organic solvent) is placed at first in the bottom of the machine, but is lifted by the cloth into the trough T. Holes at the bottom of the trough allow the liquor to fall back if required, or the holes may be closed to keep the liquor in the trough. Further, a plug at one end of the trough may be removed to allow the liquors to run away when finished. A perforated pipe, P, placed

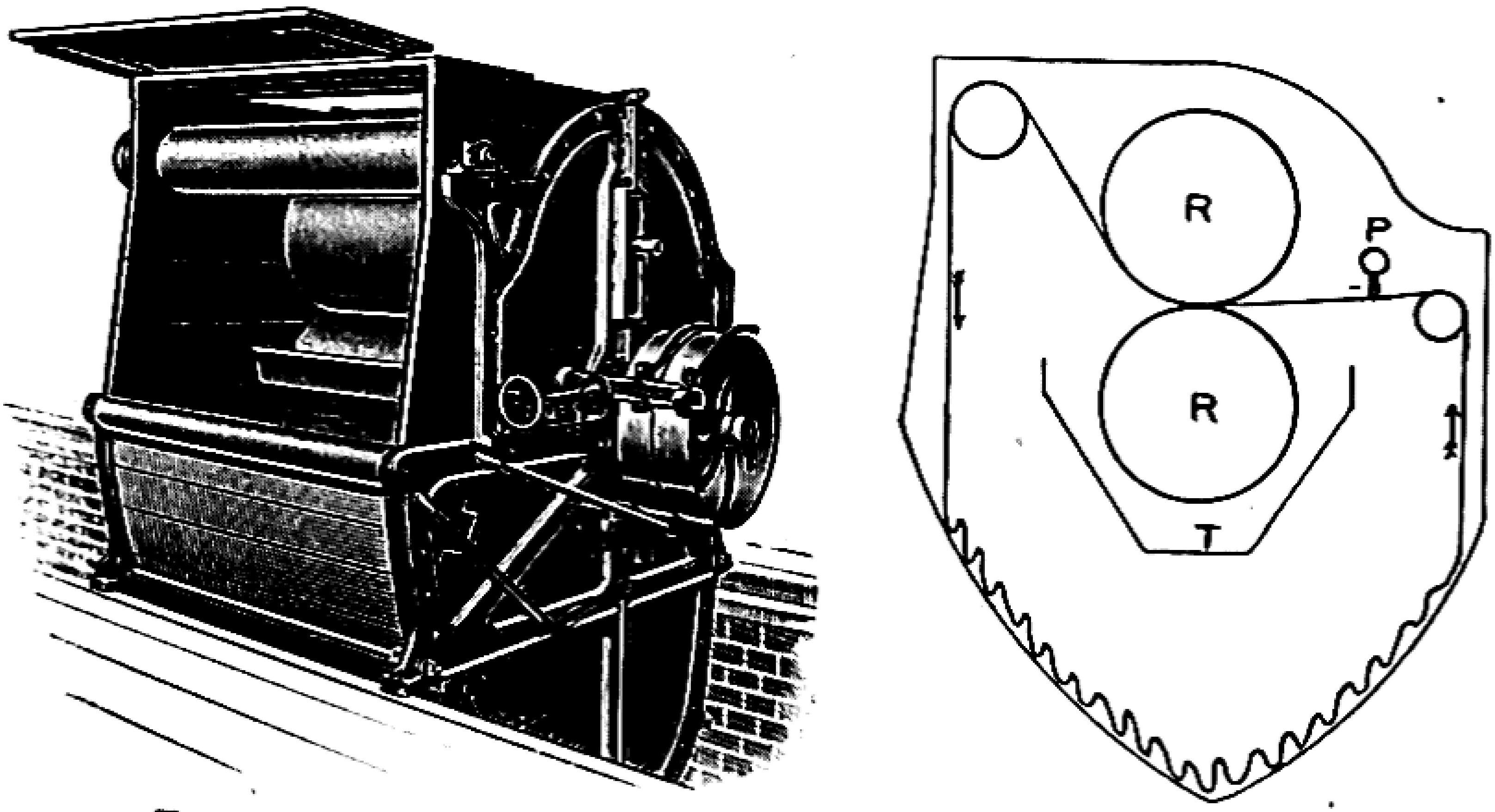


FIG. 17.—Washing and scouring machine (Whiteley's, Huddersfield).

behind the large rollers may be used to send warm water on to the cloth in the final washing.

Open-width scouring machine. This machine is shown in Fig. 18. The piece passes between the rollers at full width, but is found to give a less even scour than the dolly owing to slight irregularities in the squeeze along the rollers and also to the liquor being forced to the edges of the piece which are never properly squeezed free from liquor. Some open-width scouring machines pass the cloth over suction slits to remove excess water, but, both from the dolly and open-width machine, the liquor is generally removed by the hydro-extractor. The *hydro-extractor* consists of a wire cage which can be rotated at a very high speed (Figs. 19, 20). The wet piece is placed in the cage, which is then set in motion, and thus throws the water out of the cloth through the sides of the cage.

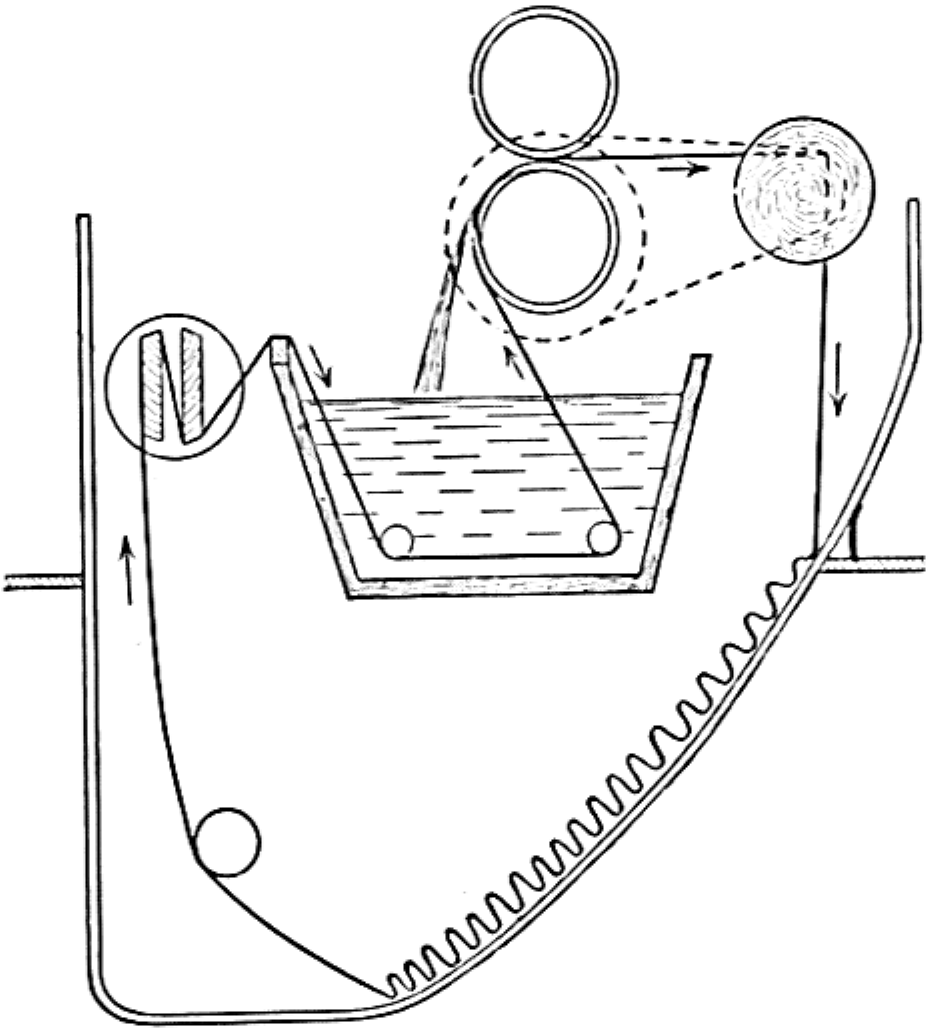


FIG. 18.—Open-width scouring machine.

Crabbing. Cotton differs considerably from wool during its treatment in scouring liquors, and different classes of yarn also vary, so that unions and many woollen pieces would present a cockled appearance after scouring. This is prevented by the process of crabbing (see p. 15). The process depends upon the pliability of the wool substance in hot water. Yarns are stretched on a frame in boiling

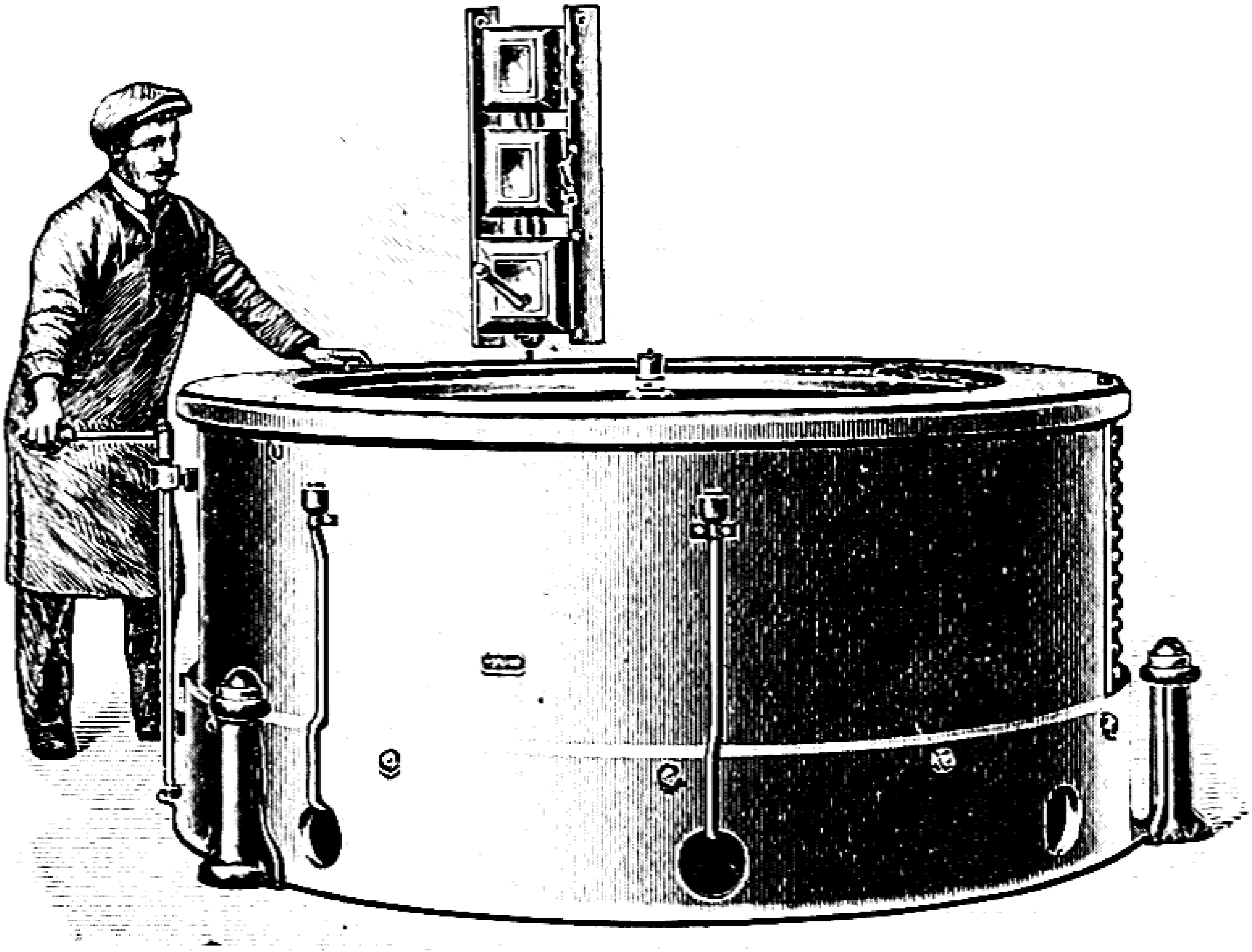
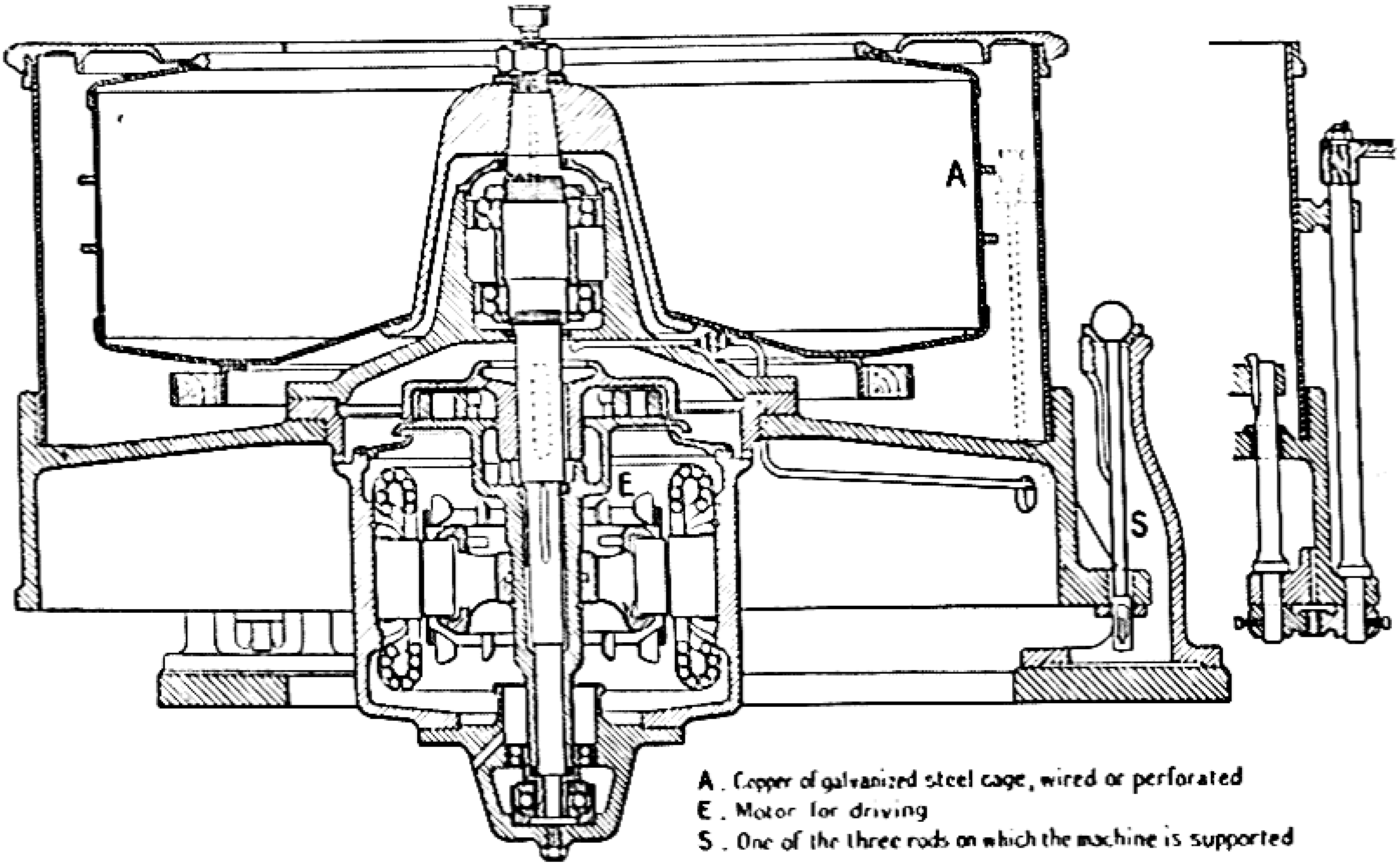


FIG. 19.—Electrically-driven hydroextractor (Broadbent's, Huddersfield).



A . Copper of galvanized steel cage, wired or perforated
E . Motor for driving
S . One of the three rods on which the machine is supported

FIG. 20.—Section of electrically-driven hydroextractor.

water and are set by allowing them to cool, or by cooling with cold water while still under tension. Pieces are crabbed by running them under tension through boiling water and tightly beaming under pressure between heavy rollers. Pieces are always crabbed before dyeing, and

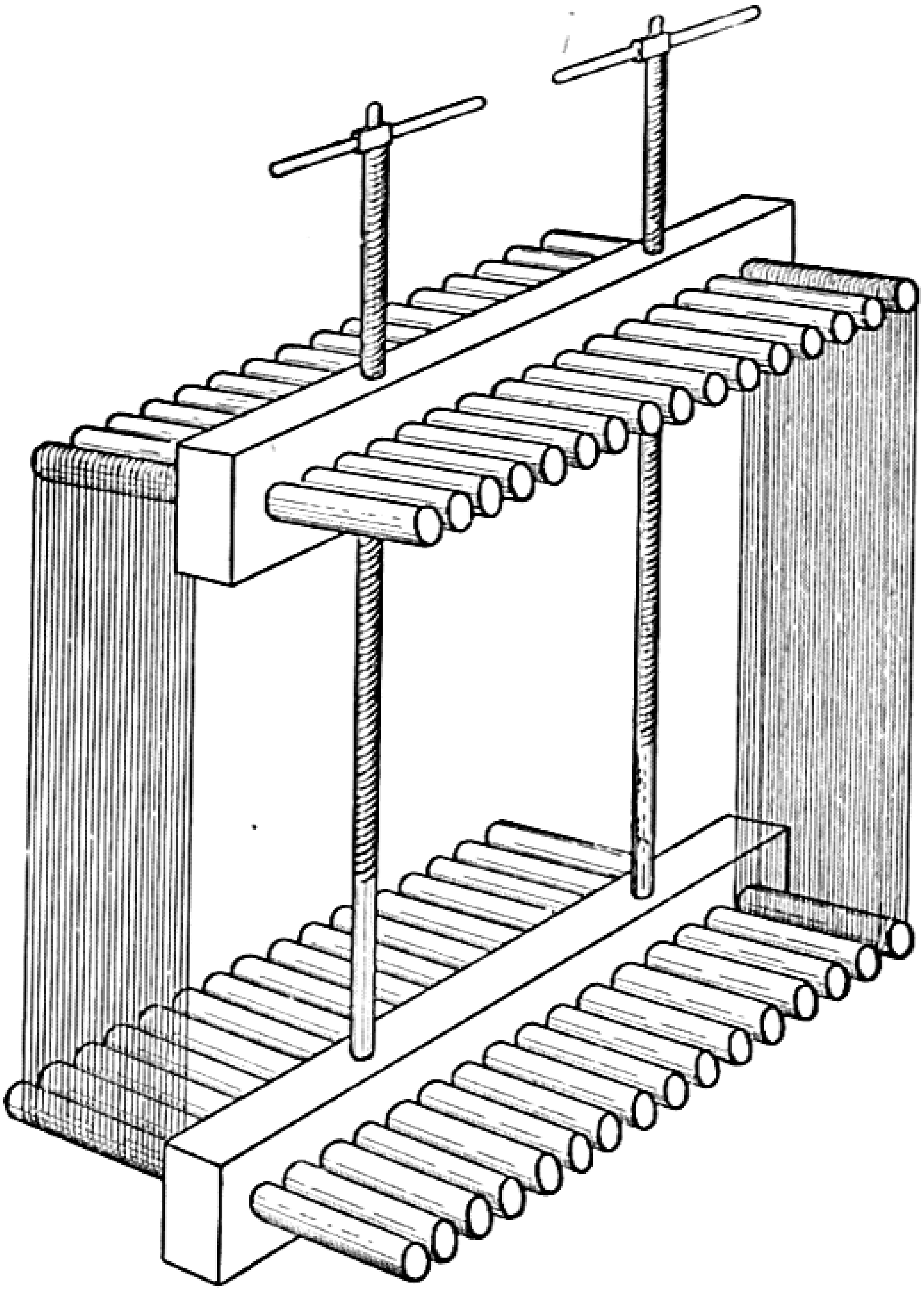


FIG. 21.—Yarn stretching frame.

also, generally, after dyeing. During the crabbing the cloth is obtained at its full width and, in addition to being "set," the cloth is given a better finish. The process is repeated to obtain a better "set" and to eliminate creases.

Fig. 22 shows the principle of the treble crabbing machine made by Messrs. Knowles & Co., Bradford.

The cloth from the beam, A, is passed, under tension, through boiling water in the trough, E, and wound on the roller, B. Considerable pressure is put on the cloth by the heavy iron roller, C_1. The amount of pressure can be regulated by an arrangement similar to that shown at H. When all the cloth is wound on B, it is rotated for a few minutes in the water. From B the cloth is wound, as in the first instance, on to B_1, boiling water being in the trough F, and from B_1 to B_2, the last trough, G, containing cold water. From B_2 the cloth passes to the rolling on beam, D.

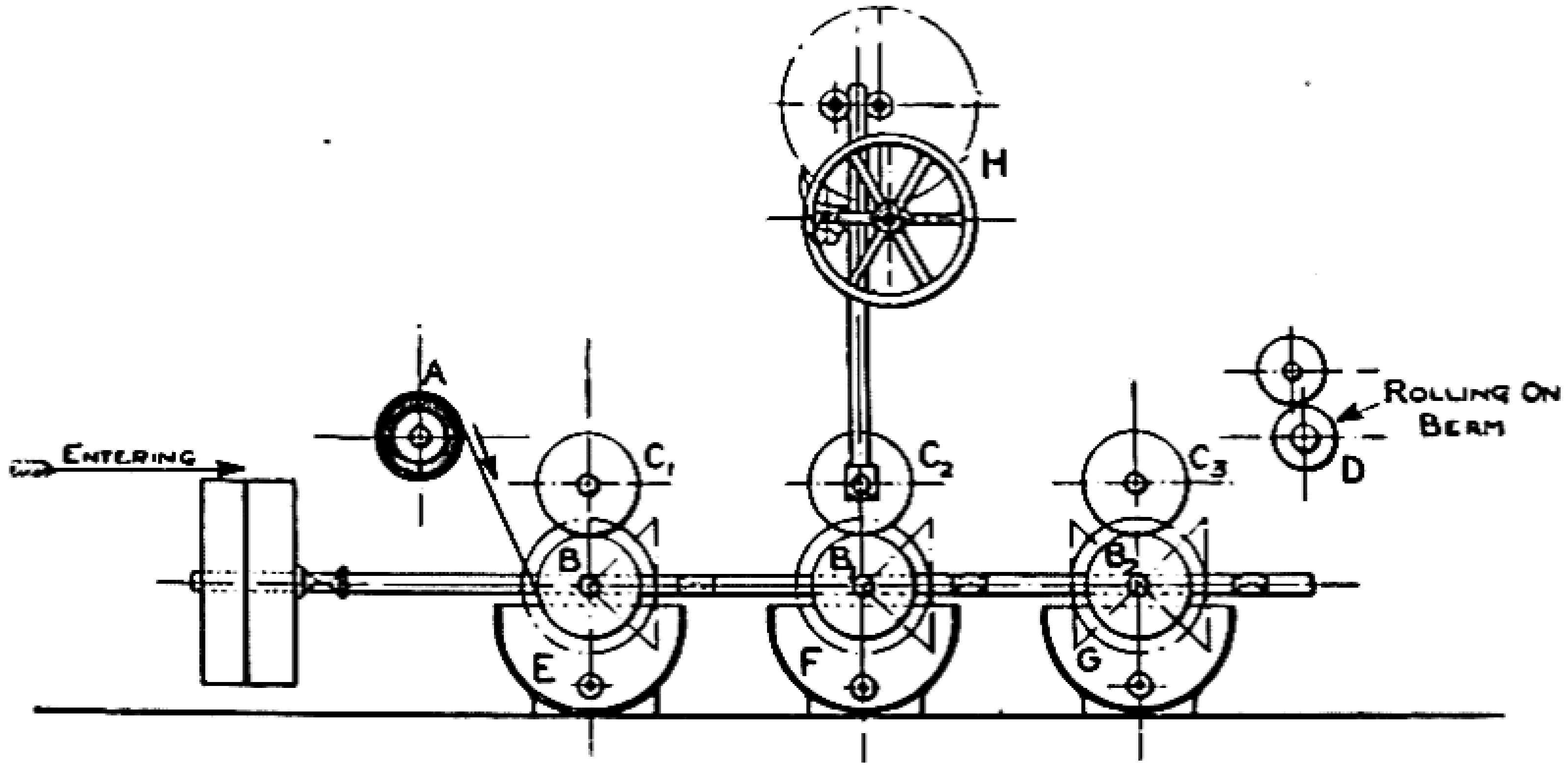


FIG. 22.—Treble crabbing machine.

The rolling on beam may be replaced by a perforated cylinder so that the process of steaming (see below) may be carried out on the same machine.

Steaming. Pieces are also given a more severe treatment, known as steaming, to give a better "setting" and a better finish. The piece is tightly wound round a perforated roller and steam forced into it. The end nearest the roller will receive a more severe treatment than the remainder of the cloth, and, if done before dyeing, will dye differently from it (p. 23). It is therefore necessary to give the piece another steaming, the end which was against the roller being this time at the outside. "Ending" is thus prevented. Crabbing a piece twice would also prevent any ending due to the crabbing, but, owing to the lower temperature used, the effect is considerably less and this is not necessary. Steaming is frequently carried out after dyeing, in which case it is known as **decatising**, and care must be taken that the dyes are fast to the treatment. One of the chief reasons for decatising is to give a better finish to the cloth. To save the labour of rewrapping the cloth for the second steaming, the roller may be enclosed in a steam-tight chamber connected to an exhaust pump. During the first treatment the steam passes through the roller to the chamber, and then the direction of the steam is reversed. The cloth is, in all cases, allowed to cool on the roller.

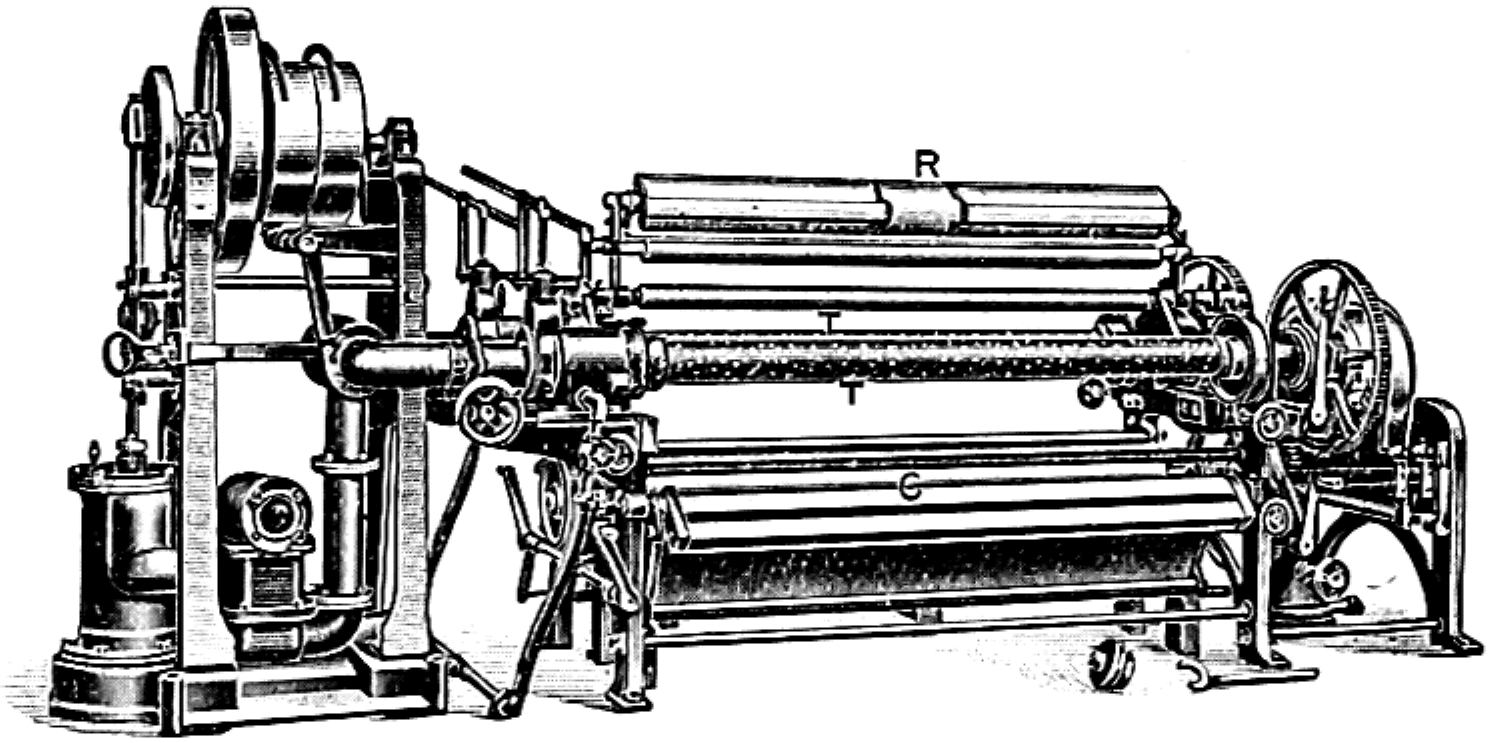


FIG. 23.—Steaming Machine (Whiteley's, Huddersfield).

Fig. 23 shows a combined crabbing and steaming machine. Two perforated tubes, T, T, are shown, the cloth being steamed first on the one and then on the other. The piece is opened out to full width on the expanding roller, R. The operation of crabbing may be carried out in the same machine, the crabbing trough being shown at C.

The perforated tubes may be connected either with steam or exhaust.

Potting. This consists in boiling pieces in water for hours or even for days, and gives a softer and denser cloth. It is used for Meltons, billiard cloths, etc.

Sizing. Woollen warps and weak worsted warps require sizing to increase their strength and to overcome the tendency to rub up during weaving. The best size is a weak solution of glue, but generally a cheaper vegetable size is employed. The size may be made of 92 per cent. flour and 8 per cent. tallow.

QUESTIONS IV.

1. Give an account of the several processes used for wool scouring.

2. Explain the following terms: deliquescence, hygroscopic, reducing agent, milling, kemps, felting.

3. What impurities are present in raw wool, and how are they removed?

4. What is the effect of steaming on the affinity of wool for dyestuffs? How is the wool fibre affected by the action of steam or water at high temperatures?

5. What is the object of crabbing worsted or union fabrics? Sketch and describe the machinery employed. Why is it necessary to crab a piece twice?

6. Sketch and describe the following: a loose wool scouring machine, a "dolly," an open-width scouring machine, a hydro-extractor.

7. Describe the methods of scouring (*a*) loose wool, (*b*) yarn, (*c*) woollen piece goods.

8. Describe an experiment to illustrate the plasticity of wool substance.

9. How would you analyse a sample of raw wool ?

10. What are the essentials of an oil suitable for spinning ? Name a few of the chief oils used.

11. Give an account of the treatment of waste wool washing liquors. State the uses to which the products obtained may be applied.

CHAPTER V

WOOL BLEACHING

Bleaching agents. Bleaching agents react with coloured substances to produce colourless substances. They may be divided into oxidising agents and reducing agents. The behaviour of oxidising and reducing agents may be learned from elementary text-books on Chemistry, and a brief account of those employed in textile work will be given as their uses are described. Alkaline bleaching agents must be used with care, because they are liable to decrease the lustre and turn the wool yellow. Chlorine and hypochlorites affect the wool fibre, and are only used to produce special effects (p. 35) and not for bleaching. When wool has to be dyed, it is not generally bleached. Flannel is often merely " blued," an acid dye being used. The blue produces a neutral tint with the natural colouring matter of the wool.

Grassing. This mode of bleaching is employed for many vegetable fibres and consists of exposing the damp material on grass to the sun's rays. It is a process of oxidation, and by some is supposed to be due to the action of hydrogen peroxide, H_2O_2, produced by the union of water with oxygen of the air, the necessary energy being supplied by the sun.

$$\underset{\text{Water}}{2H_2O} + \underset{\text{Oxygen}}{O_2} \rightarrow = \underset{\text{Hydrogen peroxide}}{2H_2O_2}.$$

The hydrogen peroxide then gives oxygen to the colouring matter of the material and bleaches it.

$$H_2O_2 + \text{colour} \rightarrow H_2O + \text{colourless matter.}$$

Others consider the bleaching due to the presence of ozone, O_3, which gives oxygen to the colour.

$$O_3 + \text{colour} \rightarrow O_2 + \text{colourless matter.}$$

There is no reason, however, why one should not consider the action to be due to direct oxidation of the colour by the oxygen of the air in presence of the sun's light.

Stoving. This is the commonest method of bleaching wool. The material is generally given a light scouring, and sometimes blued, and then hung in a chamber which can be closed. Yarns are hung over rods. Heavy pieces are also hung, but light pieces may be slowly passed up and down through the chamber on rollers at the top and bottom, the entrance and exit being pairs of rollers between which the pieces pass. Sufficient sulphur is burned at the bottom of the chamber to use up all the oxygen in the air of the chamber, and thus always produce the same effect. The sulphur dioxide formed, in presence of water, reduces the colouring substance of the wool to a colourless substance, sulphuric acid being produced at the same time.

$$H_2O + \overset{\substack{\text{Sulphur}\\ \text{dioxide}}}{SO_2} + \text{colour} \rightarrow \overset{\substack{\text{Sulphuric}\\ \text{acid}}}{H_2SO_4} + \text{colourless matter.}$$

Here the bleaching is one of reduction and is not permanent, the colour being restored by two or three months' exposure to ordinary daylight. The acid produced may be removed, if necessary, by a weak soda solution. If a blue be used to tint the wool, it must be "fast" to stoving.

Stoving may be imitated by a liquid bleach. The wool is soaked in a solution of sodium sulphite, Na_2SO_3, or, better, sodium bisulphite, and then treated with acid.

Sulphur dioxide is liberated in the fibres and bleaches as before.

$$\underset{\text{NaHSO}_3}{\text{Bisulphite}} + \underset{\text{H}_2\text{SO}_4}{\text{acid}} \rightarrow \text{NaHSO}_4 + \text{H}_2\text{O} + \underset{\text{SO}_2.}{\text{sulphur dioxide}}$$

$$NaHSO_3 + H_2SO_4 = NaHSO_4 + H_2O + SO_2.$$

Peroxide bleach. The best bleach for wool is hydrogen peroxide, which may be bought in solution or prepared from sodium peroxide and an acid. The solution is sold in strengths labelled 10, 20, or 30 volumes. The volumes represent the number of cubic centimetres of oxygen which can be obtained from one cubic centimetre of the liquid. From the equation

Hydrogen peroxide → water + oxygen

$$\underset{2\times(2+32)}{2H_2O_2} = 2H_2O + \underset{2\times16}{O_2},$$

and knowing the volume occupied by 32 grams of oxygen when as a gas, it can be shown that a 20 vols. solution contains about 6 per cent. of hydrogen peroxide, the remainder being water.

To save the cost of carriage, most bleachers prepare their own solution from sodium peroxide, a yellow powder produced by the direct union of sodium and oxygen. When added to ice-cold water, sodium peroxide forms sodium hydroxide and hydrogen peroxide,

Sodium peroxide + water (cold) → sodium hydroxide + hydrogen peroxide

$$Na_2O_2 + H_2O = NaHO + H_2O_2,$$

but with hot water the hydrogen peroxide decomposes with liberation of oxygen. Cold dilute solutions of acids also cause the liberation of hydrogen peroxide, and the bleacher adds sodium peroxide in small quantities at a time—to prevent rise of temperature—to well cooled, very dilute sulphuric acid, until the mixture is only faintly acid.

Sodium peroxide + acid → Sodium sulphate + hydrogen peroxide

$$Na_2O_2 + H_2SO_4 = Na_2SO_4 + H_2O_2.$$

Hydrogen peroxide is fairly stable in presence of acid, but unstable when alkaline. Before use, it is therefore made alkaline by adding ammonia till the liquid just smells of ammonia or turns red litmus paper blue. The wool is placed in a warm solution (40° C.) and allowed to steep overnight. The bleaching is done by oxidation and is permanent.

$$H_2O_2 + \text{colour} \rightarrow H_2O + \text{colourless substance.}$$

Permanganate bleach. Potassium permanganate is a good bleach, but is expensive. It is an oxidising agent, and when reduced gives brown oxide of manganese and caustic potash. The latter would have a bad effect on wool, and therefore magnesium sulphate is added. This forms, with the caustic potash, magnesium hydroxide, which is only feebly alkaline, and potassium sulphate.

$$\begin{array}{ccccccc} \text{Caustic potash} & + & \text{magnesium sulphate} & \rightarrow & \text{magnesium hydroxide} & + & \text{potassium sulphate} \\ 2KHO & + & MgSO_4 & = & Mg(HO)_2 & + & K_2SO_4. \end{array}$$

The wool is steeped in a weak solution of permanganate to which has been added magnesium sulphate. The brown oxide of manganese is removed from the material by steeping it in a weak solution of sodium bisulphite and adding dilute sulphuric acid. The bleaching, being due to oxidation, is permanent.

Hydrosulphite bleach. Sodium hydrosulphite, $Na_2S_2O_4$, is used as a bleach. It is a more powerful reducing agent than sulphur dioxide. The material is allowed to steep for 24 hours in a 1 to 5 per cent. solution to which a little acetic acid has been added to liberate the hydrosulphurous acid, $H_2S_2O_4$, which does the bleaching. The bleach is due to reduction and is not permanent. It is expensive.

More expensive bleaches are often used for convenience on a small scale (for household purposes). Such are "persil," a soap powder containing sodium percarbonate, and "perborin," a perborate. The percarbonates and perborates behave, when in solution, as carbonates and borates respectively, plus hydrogen peroxide, and therefore act both as detergents and oxidising agents.

$$\underset{\text{Percarbonate}}{Na_2C_2O_6} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{normal carbonate}}{Na_2CO_3} + \underset{\text{hydrogen peroxide}}{H_2O_2} + CO_2,$$

$$\underset{\text{Perborate}}{NaBO_3} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{metaborate}}{NaBO_2} + \underset{\text{hydrogen peroxide}}{H_2O_2}.$$

EXPT. 24.—**Bleaching of wool.**

1. *Stoving.* Wet out a woollen hank with soap and water, and hang in a stove overnight.

The stove may be made from a large wide mouth bottle fitted with a two-holed stopper. Through one hole place a wide glass tube passing to the bottom of the bottle, and through the other a tube bent to form a hook on which to hang the hank. Pass sulphur dioxide down the long tube until the bottle is filled, and then close both tubes with small corks.

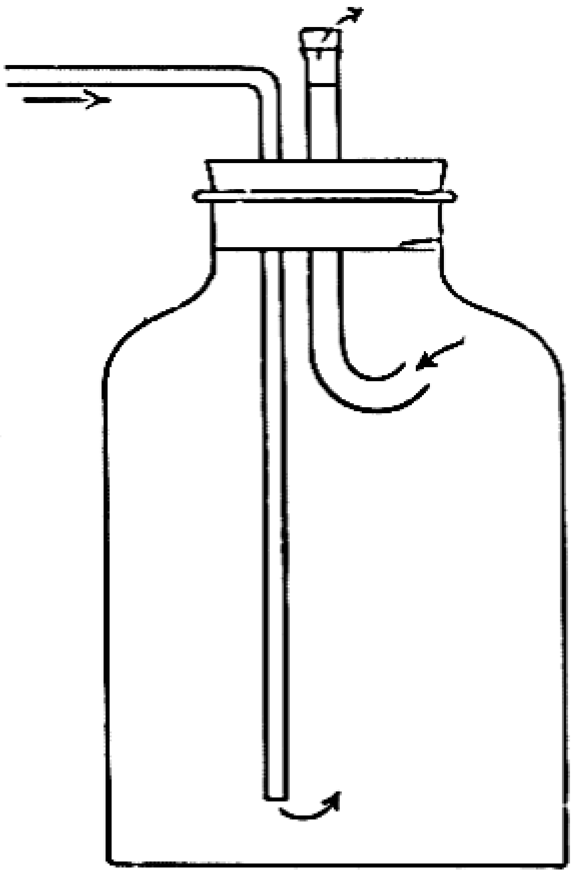


FIG. 24.—Apparatus for stoving.

2. *Bisulphite bleach.* Place a wetted out hank of wool in 150 c.c. of water + 3 c.c. sodium bisulphite solution (71 to 77° Tw.) + 5 c.c. dilute sulphuric acid. Leave overnight, wash and dry.

3. *Peroxide bleach.* Place a wetted out hank of wool in 150 c.c. water + 15 c.c. hydrogen peroxide (20 vols.) + 1 c.c. dilute ammonia. Raise in half an hour to 50° C. and leave overnight. This bleach is permanent.

4. *Permanganate bleach.* Place a wetted out hank of wool in 150 c.c. water in which is dissolved 0·2 of a gram of potassium permanganate + 0·2 gram of Epsom salts ($MgSO_4 . 7H_2O$). After one hour take out the hank, rinse it, and keep a sample.

Immerse the remainder in 150 c.c. cold water containing 4 c.c. of commercial sodium bisulphite (71-77° Tw.) + 5 c.c. dilute sulphuric acid until the brown colour disappears. Wash the hank well, and dry it.

5. *Hydrosulphite bleach.* Place a wetted out wool hank in 150 c.c. water containing 1 gram of hydrosulphite + 1 c.c. acetic acid. Raise the bath to 50° C., leave overnight, then take the hank out, rinse it and dry it.

6. *Tinting or "blueing."* This is, of course, dyeing and not bleaching, bu is frequently used after bleaching to give purer whites than the above bleaching agents would give alone.

Place a wetted out hank in 150 c.c. of water containing 1 gram of soap + a trace (less than ·005 per cent.) of Acid Violet B.N. Keep warm for quarter of an hour.

Milling. The milling of woollen fabrics causes the material to shrink, and the cloth becomes denser and more resistant to water. The operation is carried out in the **fulling or milling stocks** or in a **milling machine.** In the former, the material, wet with soap, is placed in a trough and hammered with wooden hammers. Owing to the shape of the end of the trough, the material moves round and exposes different portions to the hammer. The end of the trough may be moved horizontally so as to alter the force delivered by the hammers. The process is slow, but gives very equal felting.

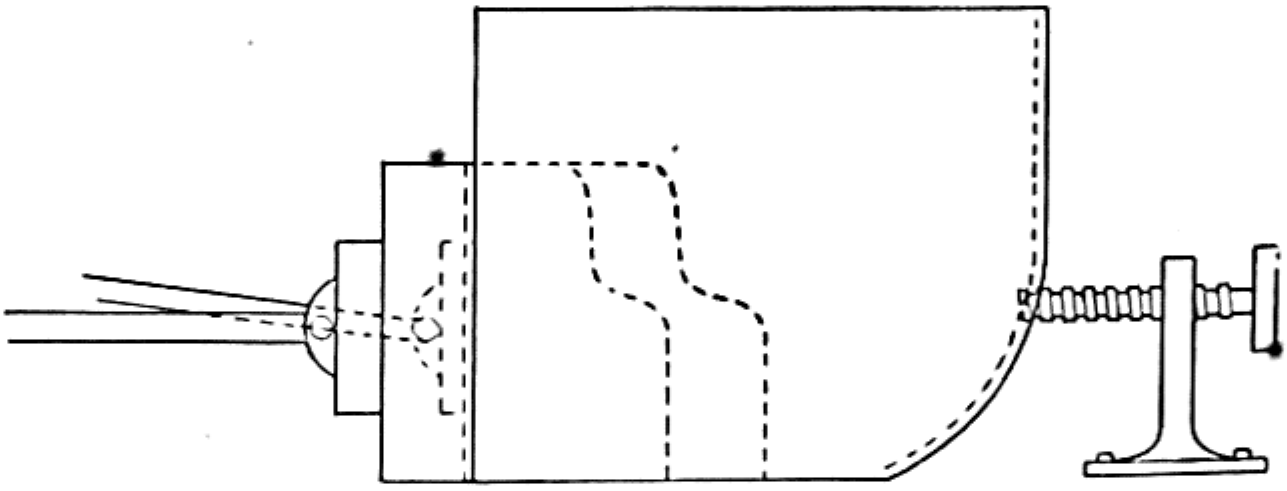


FIG. 25.—Fulling stocks.

The milling machine is much more rapid, but not quite as effective, and is more liable to produce creases. The material after soaping passes in rope form through a narrow spout which causes it to fold up and felt. Pressure applied to the top board of the spout decreases the opening and increases the felting of the material. Roberts's patent attachment to the milling machine prevents the several lengths of a piece wrapping round one another and passing in this way through the machine. It thus gives a more even felting and there is less liability to crease.

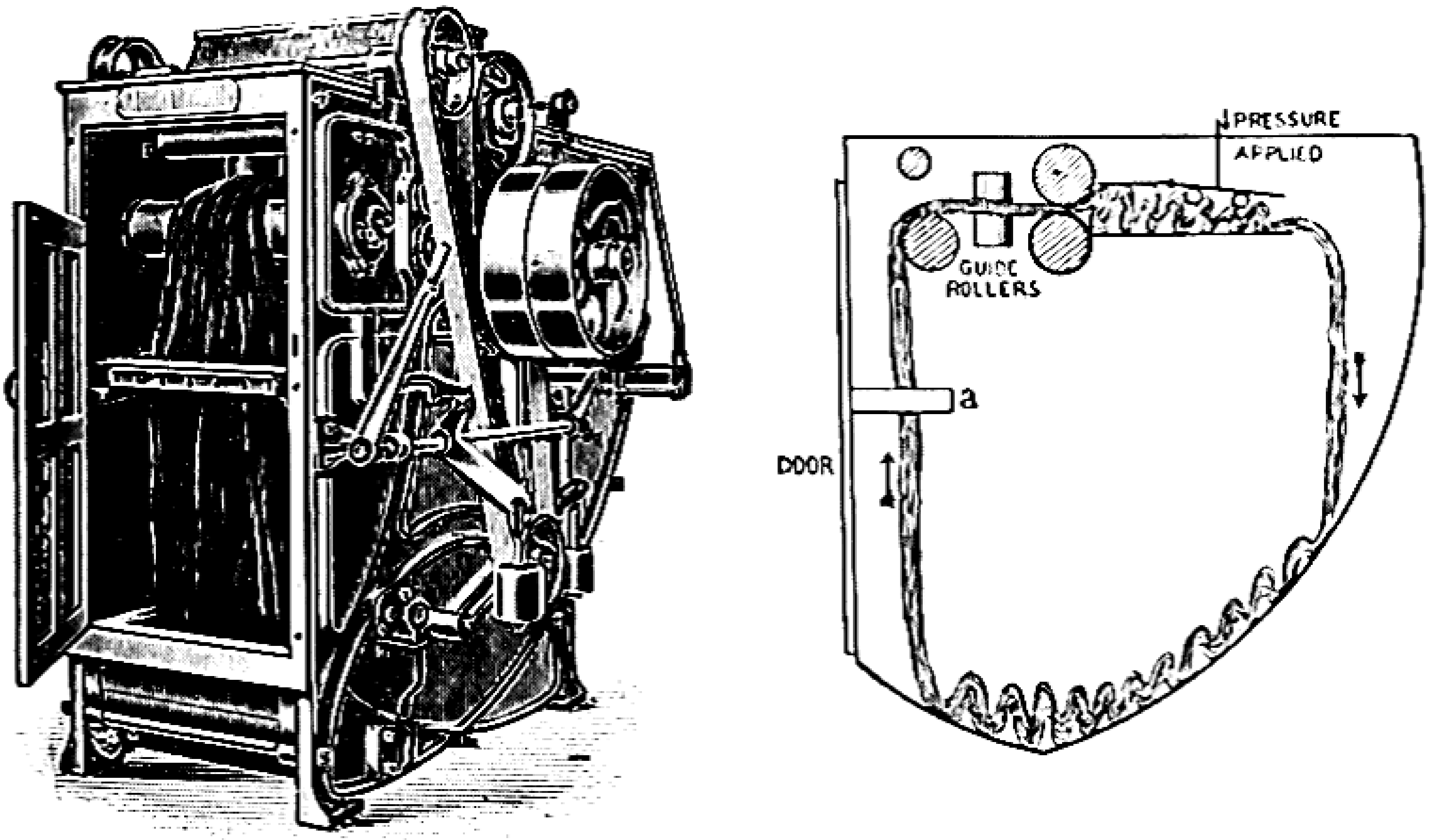


Fig. 26.—Milling machine.

a, Board through which the cloth passes; it is raised when the cloth is knotted and stops the machine.

Army blanket cloth can be shrunk from 82″ × 11½″ to 65″ × 5″. Worsteds are often given a slight milling, and unions are milled to cover up the cotton. Milling is generally done before dyeing. If carried out after dyeing, dyes must be chosen which are fast to milling. Acid milling is sometimes, but only rarely, used.

Raising, cropping, and other purely mechanical treatments of the material are omitted as being beyond the scope of the book.

Carbonisation. The principle of this process is given on page 85. Its effect is to remove from the wool, burrs and other vegetable matters. From old rags it removes cotton and linen threads. The process is applied either to loose wool or to the piece. A typical treatment for loose wool is to steep it for two or three hours in sulphuric acid, 2-3° Tw., and hydro-extract or squeeze. The wool is dried at 50° C. until the moisture has been driven off, and then heated at 100° C. The vegetable matter is converted to hydrocellulose (p. 85), which can be beaten out in a burr crushing machine. Any acid remaining is removed by soaking in water and then in a soda solution of 5° Tw. for half an hour. Piece carbonising is easier than the carbonising of loose wool owing to the large volume of the latter material. Sulphuric acid, but very frequently aluminium chloride, magnesium chloride, or even hydrogen chloride is used. Rags are generally treated with hydrochloric acid gas (hydrogen chloride, HCl). Wool treated with any of the last three, handles much better than with sulphuric acid. The aluminium and magnesium chlorides decompose during drying, liberating hydrogen chloride and forming basic salts or hydroxides.

$$\begin{array}{lclcl} \text{Chloride} & + & \text{water} \rightarrow \text{hydroxide} & + & \text{acid} \\ AlCl_3 & + & 3H_2O = Al\,(HO)_3 & + & 3HCl, \\ MgCl_2 & + & 2H_2O = Mg\,(HO)_2 & + & 2HCl. \end{array}$$

The temperature necessary is, however, generally sufficient to turn the wool slightly yellow, but this is not objectionable for certain shades of dye.

Piece carbonising is done after scouring and milling except when the piece is to be left white, when it is done before milling. Carbonising affects the milling properties. When the piece has to be dyed after carbonising it is unnecessary to remove the acid. Some pieces are carbonised after dyeing, and the dye must be fast to carbonising. The strengths of the solutions used are sulphuric acid, 6-9° Tw., aluminium chloride, 9-12° Tw., magnesium chloride, 15° Tw. A continuous drying machine is generally used and the hydrocellulose removed by dry milling. The piece must be washed and the acid neutralised.

Instead of removing the burrs by carbonisation they may be picked out with burling irons or dyed with a cotton dye to the same shade as the wool.

EXPT. 25.—**Carbonisation.** Soak an uncarbonised wool fent in cold sulphuric acid, 6-9° Tw., dry it in an air oven at 70° C. and then at 100° C. Rub it well, wash it in water, remove the acid by immersing it in a weak soda solution, then rinse it well in water and dry it.

Shoddy. This is a name commonly given to all wool obtained by tearing up woollen rags or waste. The product may be carbonised to remove cotton threads, but this is frequently omitted, and some shoddy contains a very large proportion of cotton. Material made from shoddy containing cotton is milled to cover up the cotton and then dyed. Strictly speaking, the name **shoddy** is reserved for recovered fibres from unmilled or only slightly milled woollen piece goods, shawls, knitted goods, yarns, etc., and will consist of longer fibres than **mungo**, which is obtained from strongly milled goods. The fibres in mungo vary from ¾″ to ¼″ in length, and are worked up with longer fibres. Extract wool is obtained from mixed wool and cotton waste by carbonising and washing. The product is also known as **Alpaca.** This must not be confused with the natural Alpaca hair. **Tibet wool** and

cosmos wool fibre are other varieties of recovered wool. The recovered wools are generally mixtures of variously dyed fibres, and must be stripped before dyeing except for blacks and very dark shades. As, however, some colour is always left after stripping, the shoddy fibres may be detected by the different colours of the fibres as seen under the microscope, and also by the number of foreign fibres such as cotton. Further, many of the fibres will show traces of their past history by their torn and broken appearance, and by the difference in their thickness.

Water proofing. Cloth which is waterproof has, on one or both sides, or in the interior of the material, a substance impervious to water. Such a substance is rubber, which is used in the manufacture of mackintoshes. Oilskins and tarpaulins are generally proofed with boiled linseed oil, with or without thickening agents. A solution of acetyl cellulose (p. 93) in tetrachlorethane and methyl and ethyl alcohols is used as a "dope" for aeroplane fabrics, giving them a varnish and rendering them waterproof. Water repellent or shower proof materials are not waterproof, but will withstand ordinary showers of rain. One method of shower proofing cloth is to soak it in a solution of aluminium acetate, and then dry it and heat to about 80° C. This drives off acetic acid and fixes aluminium oxide or basic aluminium acetate on the material. Another method is to soak the cloth in a solution of aluminium acetate, squeeze it, and pass it through a soap solution. An insoluble aluminium soap is deposited throughout the material. An important process is to prepare a very weak solution of resin in petroleum spirit, pass the cloth through the solution and dry it to drive off the solvent. The goods are then pressed between hot metal rollers which melt the small quantity of resin and so form a coating on the fibres. If too much resin be used, the fabric is stiffened. Glues and gelatin have been used, but cause too much stiffening. Tannic acid and chromates are used as fixing agents for the gelatin.

QUESTIONS V.

1. What is a bleaching agent ? Name a few of the principal agents used for wool, and classify them according to whether their action is due to reduction or oxidation.

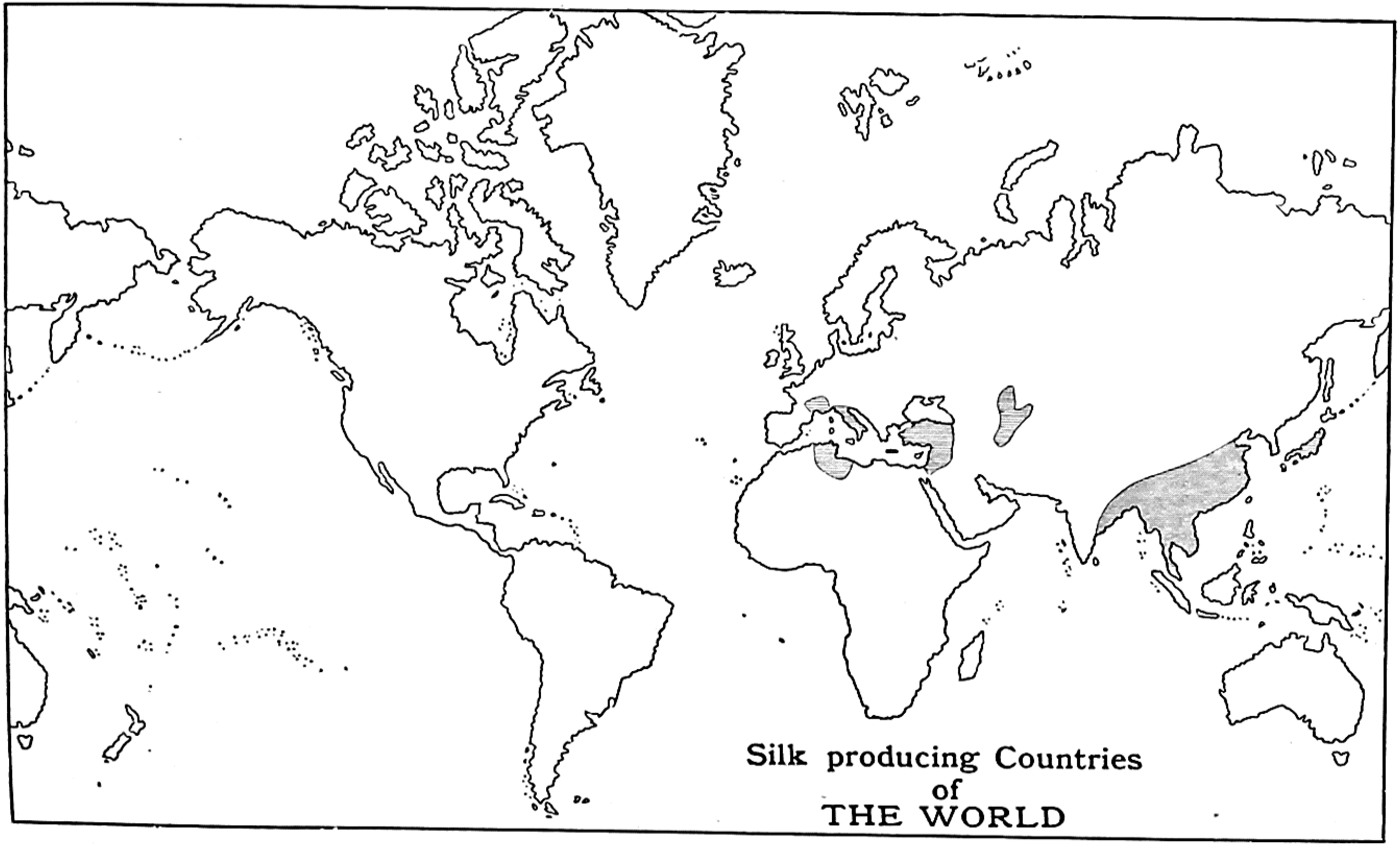
2. Describe the process of stoving wool and give the chemical action on which the bleaching depends.

3. Describe (*a*) the wash or milling stocks, (*b*) the milling machine.

4. Define the following: carbonisation, crabbing, decatising, potting, milling.

5. What is shoddy ? How would you identify shoddy by means of the microscope ?

6. Write a short account of the waterproofing of wool fabrics.



Silk producing Countries
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CHAPTER VI

SILK

Mulberry silk or true silk. This silk is produced by the silkworm, *Bombyx mori*. During the growth of the worm (thirty days) two glands in its body become filled with a thick transparent liquid which is later expelled through openings under the mouth, in the form of two fine fibres which rapidly harden on reaching the air and become cemented together as a thread. This thread is used by the worm to form a cocoon, which is built up regularly by layer on layer. The total length of thread in a cocoon is about 4000 yards. but only about 400 to 1000 yards can be obtained by reeling. The moth produced from the chrysalis must not be allowed to escape from the cocoon, for, if it does, the thread will be broken in many places and be of no use except for spun silk. The chrysalis is therefore killed by heating the cocoon to 70° or 80° C., or by means of steam.

Reeling. The cocoons are placed in warm water, which softens the gum and enables the ends of the threads to be found by stirring. Two or more of the ends are taken together and the threads drawn through agate or porcelain guides and reeled. The simplest product so obtained is termed **raw silk** or **grege**, and other varieties are produced according to the quality of the cocoons, the number of grege threads taken together, and the nature of the twist put on. **Floss silk** is the waste silk from the outer and inner parts of the cocoons, from spoilt cocoons, etc., and cannot be reeled. It is scoured in soap and soda, combed and carded, giving **échappe**, **chappe** and **florette** silks, while the poorer shorter fibres (silk noils) give **bourette** silk.

Microscopic appearance of the silk fibre. Raw silk consists of two silk fibres cemented together by the silk gum. **Boiled-off silk** appears as a transparent fibre with few longitudinal striations. A cross-section shows an irregularly shaped structureless fibre. Under very high powers the fibre shows a fibril structure, *i.e.* the fibres appear to be made up of still finer fibres. The fibril structure is more apparent in **wild silks.**

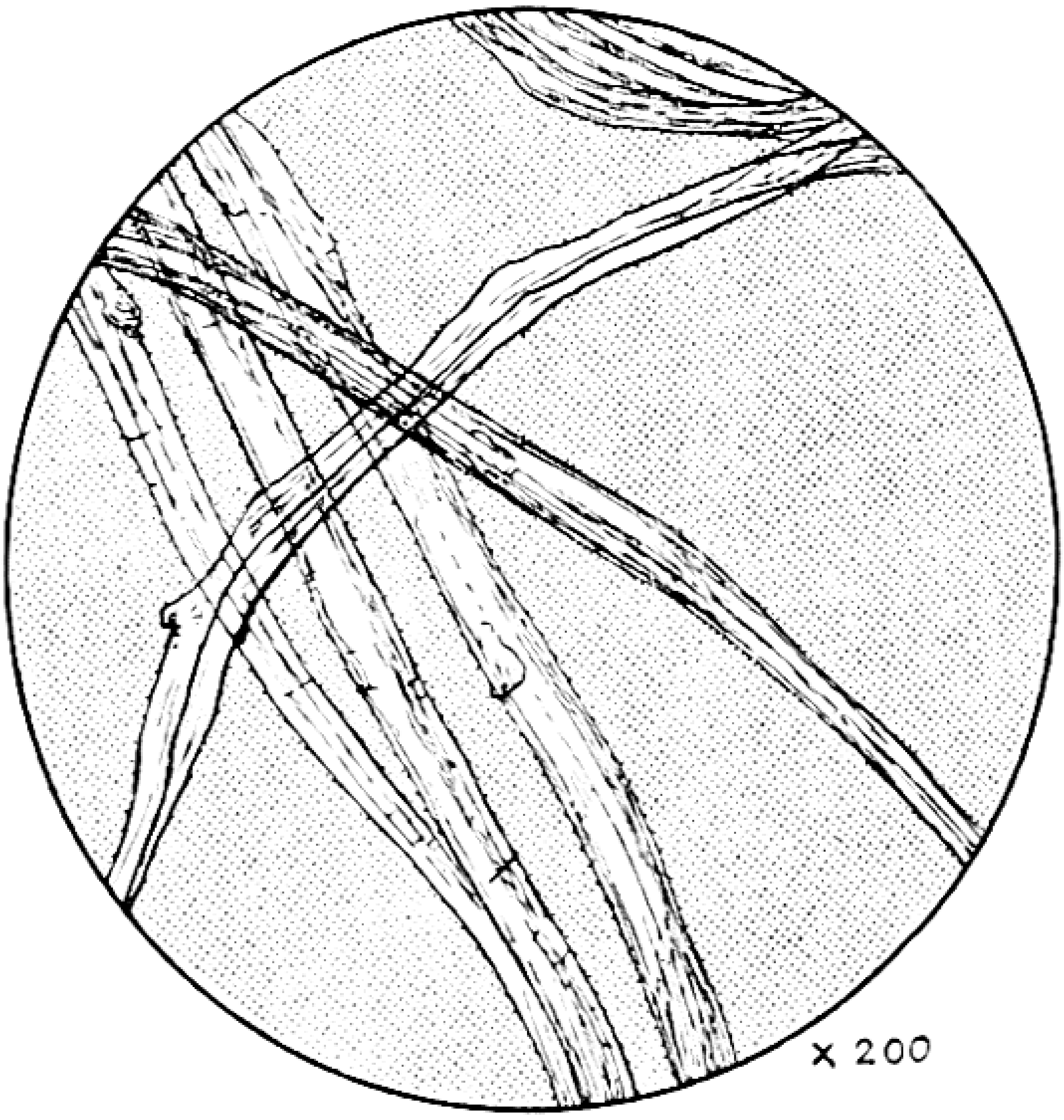


FIG. 27.—Microscopic appearance of raw silk.

Physical properties of the silk fibre. The diameter of raw silk varies with the kind of silk and with the portion of the cocoon from which it is taken. Raw silk is stiff and dull, but when boiled off with soap it yields a fine soft glossy fibre characterised by great strength and elongation. Raw silk may be stretched one-fifth to one-seventh of its length, and has a breaking strain of 64,000 lbs. per square inch or 45,000 grams per sq. mm. (equal to the tensile strength of steel wire). When boiled off, silk loses 20 to 40 per cent. of its strength and 45 per cent. of its elongation. Silk is very hygroscopic and expensive, and therefore conditioning is necessary. The material is heated at 140° C. until there is no further loss, and a regain of 11 per cent. is allowed on raw silk and 9·25 on boiled-off silk.

EXPT. 26.—**Moisture in silk.** Weigh a sample of the silk and heat it in an air oven at 140° C. till its weight is constant. Calculate the percentage loss.

Silk is a bad conductor of electricity, and when subjected to friction becomes electrified and is difficult to manipulate. If the atmosphere be moist this electrification is prevented. The lustre of silk is one of its most striking properties, but only appears when degummed or boiled off. Silk yarn is submitted to various mechanical processes of shaking, glossing, and lustreing to increase its softness and brilliancy.

Boiled-off or partly boiled-off silk, when treated with a dilute acid and dried without washing, acquires a **scroop**, *i.e.* gives a rustling sound when rubbed. Tartaric acid is the best to use, and citric acid is also good, but acetic acid and sulphuric acid are not satisfactory.

Composition of silk. Silk contains no sulphur. Raw silk consists of two substances, **sericin** and **fibroin.** The latter is the true silk fibre and is a protein similar to the substance of the wool fibre. Like wool it yields amino-acids on hydrolysis. **Sericin** has a slight yellow tinge, and is the **silk gum** or glue which cements the two fibres together. It is soluble in hot water, and is easily removed from the fibre by boiling with soap solution. The formulae of sericin and fibroin are not known with certainty, but that of fibroin is approximately $C_{15}H_{23}N_5O_6$, and some consider that there is a simple relation between fibroin and sericin which may be given as follows:

$$\overset{\text{Sericin}}{C_{15}H_{23}N_5O_6} + \overset{\text{water}}{H_2O} + \overset{\text{oxygen}\rightarrow}{O} = \overset{\text{fibroin}}{C_{15}H_{25}N_5O_8}.$$

The colouring matter in raw silk seems to depend upon the kind of leaves on which the silkworm feeds.

Bast soap. The liquor obtained by boiling off silk with soap solution is known as boiled-off liquor or bast soap, and contains the silk gum and soap. It is used in the dyeing of silk to prevent injury to the fibre, and, at the same time, a more even dyeing is obtained. Chinese and Japanese silks lose 18 to 20 per cent. in weight and European silks 25 to 40 per cent. during boiling off.

Soupling. Soupling is a process for producing the boiled-off silk appearance without removing more than 4 to 8 per cent. of the gum. The partly boiled-off silk is treated with cream of tartar which makes it fine and more absorbent.

Écru silk is dyed after only wetting out. Very little gum is removed.

EXPT. 27.—**Treatment of silk**. In order to save expense, the samples of silk used in this and following experiments weigh 0·5 of a gram each, and consequently greater care must be taken with the weighings.

Weigh out five 0·5 gram samples of raw silk.

Boiling off.—(*a*) Treat Nos. 1, 2, and 5 for 1 hour at 90-95° C. in 100 c.c. water containing 0·5 gram of pure olive oil soap. Rinse sample No. 1 in cold water, allow it to dry in air, and weigh it. Calculate the percentage loss. Mount a portion of No. 1.

(*b*) Further treat No. 2 in 100 c.c. water containing 0·5 gram of soap for 1 hour at 90-95° C. Wash and dry the sample, and calculate the further decrease of weight.

(*c*) Treat sample No. 3 for 1 hour at 90-95° C. in 100 c.c. of water containing 0·5 gram of soap + 0·1 gram of soda ash. Calculate the percentage decrease.

Soupling. Treat No. 4 sample for three-quarters of an hour at 50° C. in 100 c.c. water containing 0·5 gram of soap. Souple in 100 c.c. water containing 0·1 gram of tartar + 0·25 c.c. sodium bisulphite solution (71° Tw.) + 0·2 gram sulphuric acid at 60° C. for three-quarters of an hour. Wash the sample well with warm water and then with cold.

Scrooping or brightening. Treat sample No. 5 for 10 mins. in 100 c.c. warm water containing 0·5 gram of tartaric acid. Dry it without washing. This scrooping is often done after dyeing.

CHEMICAL REACTIONS OF SILK.

Water. Silk is more resistant to water than wool, and water at 150° C., which rapidly dissolves wool, leaves silk almost unaffected.

Acids. Silk, like wool, has the property of uniting with dilute acids, but at the same time acquires a scroop. Concentrated sulphuric acid slowly dissolves silk, but if only allowed to act for one or two minutes, and then the silk be rinsed and neutralised, a shrinkage of 30 to 50 per cent. is observed. Nitric acid turns silk yellow. Strong hydrochloric acid dissolves silk very rapidly, and may be used to estimate the amount of silk in a mixture of wool, silk, and vegetable fibres. Strong hydrochloric acid will dissolve more than its own weight of silk. Hydrochloric acid of suitable strength, and also certain solutions of zinc chloride, can be used to produce shrinkage of silk and may be employed for the production of crepe effects. Cold dilute solutions of hydrofluoric acid, HF, do not affect silk, but remove inorganic matter. Nitrous acid diazotises silk (p. 182), and the diazotised silk may be dyed by coupling it with β. naphthol, etc. Silk differs considerably from wool in its behaviour towards tannic acid. It absorbs the acid readily from cold solutions, and takes up 25 per cent. of its weight from hot solutions. The tannic acid, unlike that absorbed by cotton, is held strongly. Chromic acid apparently attacks silk, and under the microscope many striations are seen on the fibre.

EXPT. 28.—**Effect of acids on silk.** Carry out trials similar to those given for wool in Expt. 14, and in addition, try the effect of strong acids on small pieces of silk in test-tubes.

Alkalis. Silk is less sensitive to alkalis than wool, but its lustre is diminished. Strong cold solutions of caustic alkalis at 0° C. have very little action, and may be used to produce crepe effects in a silk and cotton mixture. The cotton shrinks (see mercerisation, p. 88). Hot caustic alkalis dissolve silk, but not as readily as they dissolve wool. Weakly alkaline solutions, such as soap and ammonia, have no effect. Borax solutions do not remove sericin. Lime water causes the fibre to become brittle.

EXPT. 29.—**Effect of alkalis on silk.** Carry out trials similar to those in Expt. 16.

Salts. Common salt deteriorates silk, especially weighted silks. Towards mordants silk exhibits great affinity, and unites with them to such an extent that they may be used for **weighting.** By the weighting of silk is meant the fastening on to the silk fibre of substances whose presence is simply to increase the weight of the material. The weighting may be carried out before, during, or after dyeing, and may vary from "weighting to par" (*i.e.* equal to the loss in weight of the silk during boiling off) up to 300 per cent. When carried out before dyeing, such salts as stannic chloride, tin phosphate, or tin phosphate and silicic acid are used. During and after dyeing, tannins, sugar, etc., may be used. Weighted silks deteriorate on standing in sunlight, but the deterioration may be decreased by the addition of certain substances. Boiling concentrated solutions of basic zinc chloride dissolve silk in one minute, while cotton only loses 0·5 per cent. and wool 1·5 to 2 per cent. Acid zinc chloride behaves similarly. Ammoniacal copper oxide (p. 92) and ammoniacal nickel oxide (p. 146) dissolve silk, but the latter does not dissolve cotton. Silk is also soluble in strong solutions of stannic chloride.

Chlorine and hypochlorites. These have, except in very dilute solutions, a great action on silk.

Silk bleaching. With the removal of the sericin almost all of the colouring matter of mulberry silk is removed and a white silk obtained, but in some cases bleaching is resorted to. Stoving is the method generally employed, but hydrogen peroxide may be used. For souple silk and for Tussah silk, aqua regia is employed.

Expt. 30.—**Bleaching of silk.**

1. Boil off ½ grm. sample, as in Expt. 27 *a*, and stove as for wool in Expt. 24.

2. Boil off ½ grm. sample, as for No. 4 in Expt. 27, and before soupling immerse it in cold aqua regia, 4½° Tw., until a light greenish-grey colour. If allowed to stay too long, a permanent yellow colour is given to the fibre. Now souple the sample and wash it as before. The greenish-grey colour will be removed.

3. Treat ½ grm. sample, as in 2, but stove it instead of using aqua regia.

4. Wet out ½ grm. sample and stove it. This gives bleached écru silk.

5. *Tussah silk.* Wet out a sample with boiling water, then boil it for 1½ hours in 100 c.c. water + 1 grm. soap + 0·5 grm. soda ash. Rinse the sample and transfer it to 100 c.c. water + ½ c.c. comml. hydrochloric acid. Bleach it with hydrogen peroxide as follows: Prepare a bath of hydrogen peroxide as for wool, but make it alkaline with sodium silicate, and add 1 grm. of olive oil soap dissolved in a little hot water. Work the sample cold for half an hour, then raise it nearly to the boiling point, and leave overnight. Wash it well.

6. *Tussah silk.* Boil off a sample as before and bleach it with potassium permanganate. Prepare a solution as for wool and allow the silk to remain in it overnight. Remove the brown oxide with bisulphite, and then boil the sample in 100 c.c. water + 1 grm. of soap for half an hour.

Silk gum is rendered less soluble in water by treatment with formaldehyde or with tannic acid.

Expt. 31.—**To fix the silk gum.**

(*a*) Place ½ grm. sample of silk in 100 c.c. water containing 4 c.c. of formalin, raise to the boiling point in half an hour, and boil for a quarter of an hour.

Formalin is a solution (40 per cent.) of formaldehyde, $HCHO$, in water.

(*b*) Place ½ grm. sample in 100 c.c. water containing 2 grms. of tannic acid and treat it as above.

Dyes. Silk has a very great affinity for dyes, and like wool, which exhibits basic and acidic properties, may be dyed directly with acid, basic, and salt colours. In nearly all cases bast soap or a substitute is used in the dye bath.

Experiments should be carried out as in Expt. 23.

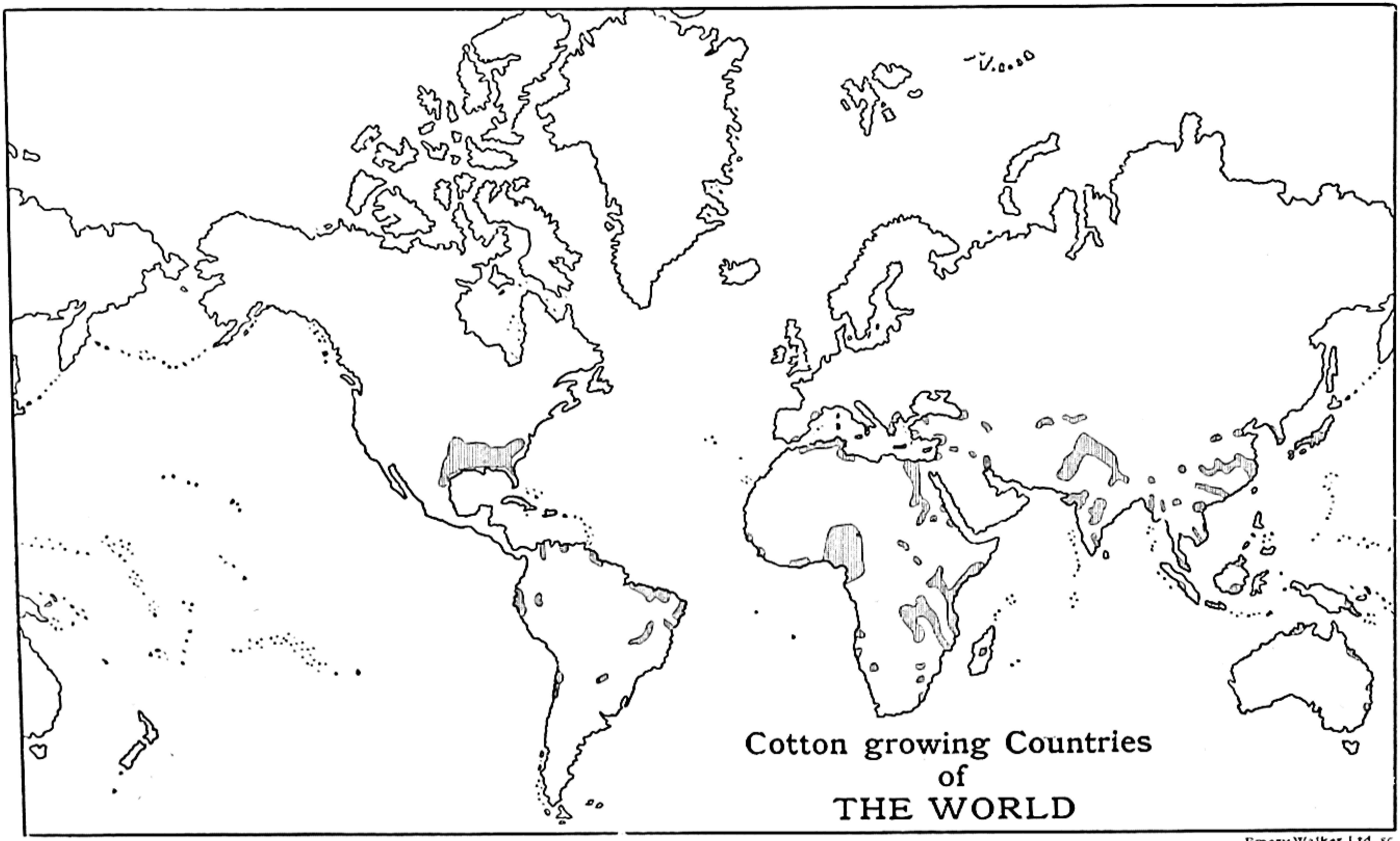
In the case of acid, basic, and salt dyes, try the effect of using in the bath (*a*) bast soap, (*b*) olive oil soap, (*c*) boiled-off liquor substitute (p. 172), and compare the results with the dyeings obtained without the use of these. Refer to text-books on dyeing for particulars.

Wild silks. Tussah, Eria, and other silks are the products of the larvae of moths belonging to the genera

Antherea and *Attacus*. The cocoons are much larger but less regular than those of the *Bombyx mori*, and reeling is extremely difficult and seldom attempted. The fibres are much thicker and less uniform in diameter than the true silk, and frequently show a twisted appearance. They also have a large number of longitudinal striations. On account of their greater thickness they possess great strength. They are much more resistant to chemical action than true silk. The gum is not easily removed, and the fibre is highly coloured and very difficult to bleach. A hot 10 per cent. solution of caustic soda dissolves true silk in 12 minutes and Tussah silk in 30 minutes. Cold concentrated hydrochloric acid dissolves true silk very rapidly, but Tussah silk is only slightly affected in 48 hours.

QUESTIONS VI.

1. Give the composition of raw silk, and state what happens when the silk is boiled with a dilute solution of soap and soda.
2. What is boiled-off liquor, and for what is it used ? How would you prepare a substitute for boiled-off liquor ?
3. Compare the chemical behaviour of silk and wool. How would you remove silk from a union of silk and wool ?
4. What do you mean by (*a*) soupling, (*b*) scrooping, (*c*) écru silk, (*d*) bast soap ?
5. Give an account of the physical properties of the silk fibres, and state on which of these you think the value of silk depends. In what respects is mulberry silk more valuable than (*a*) wild silks, (*b*) artificial silks ?
6. Why is it necessary to condition silk ? How is this conditioning carried out ?
7. Explain fully the uses of conditioning houses.



Cotton growing Countries
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CHAPTER VII

COTTON

Varieties of cotton. Cotton is a seed hair and consists of the hairs or fibres which are attached to the seeds in the seed pods of the various species of the plant *Gossypium*. Each fibre is attached to the seed at one end and is rounded at the other, the whole representing a single plant cell. The cotton plant varies according to the species and to the locality in which it is grown, and may be herbaceous, shrub, or tree. Some botanists place the number of species as high as eighty-eight and others as low as three. Only two classifications are given here. The first consists of seven species as follows:

Gossypium Barbadense, which supplies the long-stapled Barbadoes, Sea Island, Egyptian, and Peruvian cottons.

Gossypium hirsutum, giving the Lousiana and uplands cotton.

Gossypium herbaceum, which supplies the cottons of India, Siam, China, Italy, etc.

Gossypium arboreum of Ceylon, Arabia, S. America, etc.

Gossypium Peruvianum, supplying the native varieties of Peruvian and Brazilian cottons.

Gossypium Tahitense, found in Tahiti and the Society Islands.

Gossypium Sandwichense of the Sandwich and adjacent islands.

The second classification consists of the four principal species cultivated for commercial purposes, viz. *Gossypium Barbadense*, *G. hirsutum*, *G. herbaceum*, and *G. arboreum*.

Gossypium Barbadense supplies the most valuable cotton. The species is a shrubby perennial, six to eight feet in height, but is cultivated as a herbaceous annual or biennial. The flowers are yellow, and the fibres long and white. The seed pod is divided into three cells, each containing six to nine black seeds from which the fibres are easily separated.

Gossypium herbaceum is also a perennial, four to six feet in height, cultivated as an annual or biennial. The flowers are pale yellow, and the fibres white and silky. The pod is divided into three to five cells, each containing from five to eleven seeds. The seeds are covered with two kinds of fibre, one short and dense, and the other much longer. The fibres are not easily separated from the seeds.

Gossypium hirsutum is considered by many to be a variety of *G. herbaceum* although it differs from it in its seeds, which are covered with a green-tinted down.

Gossypium arboreum is a tree reaching a height of fifteen to twenty feet. The flowers are red, and the seeds are covered with a green down surrounded by a yellowish white fibre of good quality.

The cotton seed pod. The pod or boll has a hard outer covering, and is divided internally into cells which vary from three in Egyptian to four or more in American. The number of seeds in each cell varies from five to eleven, each seed being surrounded by the fibres. When the pod is ripe it bursts open, and shows a mass of white downy fibres in which are embedded the seeds.

Ginning. The cotton is picked as soon as possible after ripening, and the fibres are separated from the seeds by ginning. There are two kinds of machine for the purpose, viz. the roller gin and the saw gin. The roller gin is used for the long-stapled high-class cotton and the saw gin for the shorter stapled cottons. With the increasing speeds given to the saw gins in order to attain greater output, there is much tearing of the fibres and a consequent reduction in the value of the cotton. The seeds are used in the production of cotton seed oil and cake, and as they contain tannin it is essential that they should not be crushed during the process of ginning, because the tannin would then be taken up by the cotton and might give trouble in the later process of dyeing.

Cotton seed products. Uplands cotton seeds are not entirely freed from the fibre by the first process of ginning, but are left covered with fine hairs. These are removed by a second (and sometimes a third) ginning with saws having finer and more closely set teeth. The first ginning gives cotton, known as **lint**, while the product of the second ginning is called **linters** and is generally used for **batting** (wadding). The outer casings of the seeds are known as **hulls** and are split off before pressing the seeds for oil. The hulls were formerly burned for fuel, but when mixed with cotton-seed meal are found to provide a good food for cattle. **Cotton-seed oil** may be cold drawn, *i.e.* pressed from the seeds without previous heating, or obtained by heating the seeds and then pressing. The oil obtained by the first process is the more valuable. The oil is refined and is used for cooking, soap making, margarine manufacture, as a cheap substitute for olive oil, etc. After pressing the oil from the seeds, a compact cake is left which is broken up and ground to **meal.** The meal is used either as a food for cattle or as a fertilizer.

Analysis of the cotton plant. An average analysis of the dried cotton plant gave

	Per cent.
Roots	8·80
Stems	23·18
Leaves	20·28
Bolls	14·12
Seed	23·05
Lint	10·57

and the seeds of an upland cotton yielded roughly

	Per cent.
Meal	34
Oil	20
Hulls	36
Linters	10

Microscopic appearance of cotton. The cotton fibre appears under the microscope as a twisted flattened tube. The number of twists varies considerably with the kind of cotton, and is greater in cultivated than in uncultivated cotton. The cross-section of the fibre shows a thick wall and a large central canal or lumen. Certain fibres may be found which have no lumen and are stiff and white. These are unripe fibres. By treatment under the microscope with reagents the fibre is found to be surrounded by a hard cuticle or skin, and the walls of the central canal are more resistant to the action of chemicals than the chief substance (cellulose) of the fibre.

Physical properties of cotton. The fibres vary in length from a maximum of 4·05 cm. in Sea Island cotton to a minimum of 1·03 cm. in Indian, and in diameter from 0·0019 cm. in the former to 0·0037 cm. in the latter ; the finer the fibre, the longer the staple. The diameter given is the mean diameter. Cotton has an elongation of 4 per cent., and its tensile strength is slightly more than that of human hair (p. 13), the breaking strain varying from 5·4 grms. in Sea Island to 10 grms. in Indian. Cotton is less hygroscopic than wool or silk, and generally contains about 7 per cent. of moisture. The spinning properties of raw cotton depend largely upon the amount of moisture present. Cotton freed from its fatty and waxy impurities is capable of absorbing eighteen times its own weight of water.

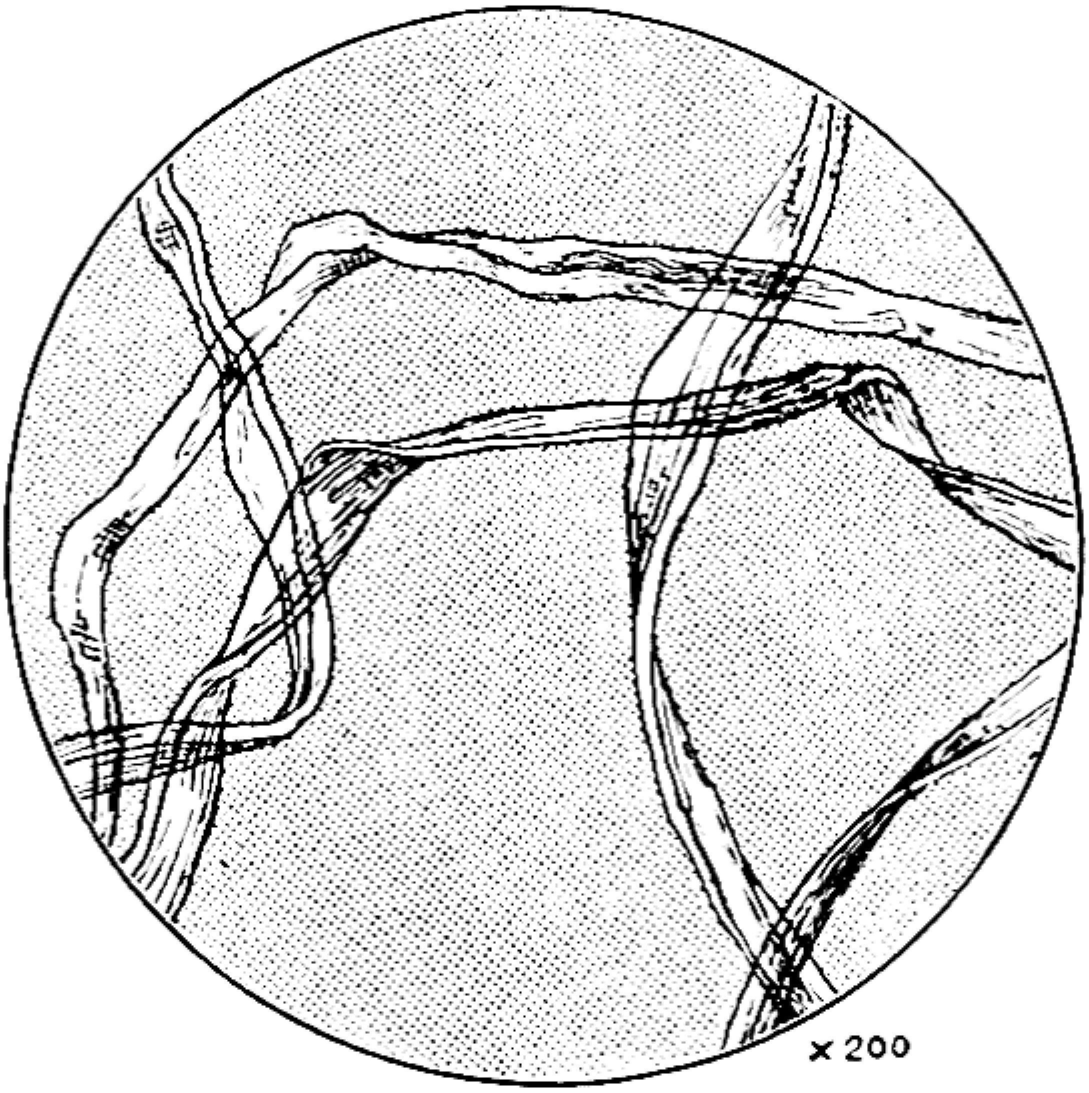


FIG. 28.—Microscopic appearance of cotton fibres.

Composition of raw cotton. **Cellulose** $(C_6H_{10}O_5)_n$ is the principal constituent of cotton, being present to the extent of 83 to 86 per cent. Cotton wax, which gives a thin protective covering to the fibres and makes raw cotton difficult to wet out, melts at 85·9° C., and is identical with carnauba wax. The fatty acid present is probably margaric acid. In addition to the wax there are, as essential constituents of the raw fibre, albuminous or nitrogenous matters, pectic acid, mineral and colouring matters and water. An analysis of an American cotton gave

	Per cent.
Cellulose	83·91
Nitrogen free extract	5·76
Wax	0·61
Nitrogenous matter	1·50
Ash	1·65
Water	6·57

CHEMICAL REACTIONS OF COTTON.

The chemical properties of cotton will be known if the reactions of cellulose are known. Cellulose is a carbohydrate allied in composition to starch, $(C_6H_{10}O_5)_x$, grape sugar, $(C_6H_{12}O_6)$, cane sugar, $(C_{12}H_{22}O_{11})$, and dextrin, $(C_6H_{10}O_5)_m$, but is much more resistant to chemical agents than these substances. Its percentage composition, calculated from its formula, is

	Per cent.
Carbon	44·4
Hydrogen	6·2
Oxygen	49·4

Expt. 32.—**Effect of heat on cotton.** Heat a little cotton in a dry tube. The products of distillation of cellulose are similar to those obtained in wood distillation ; carbon, water, acetic acid, acetone, and methyl alcohol are produced.

Expt. 33.—**The burning of cotton.** Light a cotton thread and notice how quickly it burns. No bead of carbon is left as in the case of wool, but only a very small quantity of white mineral ash. The smell is like that of burning paper.

Water. Cotton is unaffected by boiling water and even by water at 150° C. (compare wool and silk). At 160° C. a slight effect takes place and at 170° C. considerable changes are produced, hydrocellulose probably being formed. Steam under high pressure rapidly disintegrates the fibre.

Acids. Very dilute solutions of sulphuric acid have no appreciable action, but if allowed to dry on the fibre, the latter becomes tendered owing to the formation of hydrocellulose and the fibrous structure is lost. The product is a pulverulent substance which can very easily be rubbed or shaken to powder. This action is made use of in carbonisation (p. 64).

Hydrochloric acid behaves similarly to dilute sulphuric acid. Non-volatile organic acids, such as oxalic acid, which can dry on the fibre, behave like sulphuric acid and cause tendering, but volatile organic acids, such as acetic and formic acids, have very little action, and may be used where an acid is required at high temperatures, *e.g.* in calico printing. The tendering of cotton dyed with sulphur colours is caused by the production of sulphuric acid through the oxidation of the colours. Hydrocellulose is soluble in alkalis, and reduces Fehling's solution (p. 182) and an ammoniacal solution of silver nitrate. A filter paper (or unsized paper) when immersed in sulphuric acid (Sp. Gr. 1·5-1·6) for a short time, becomes transparent, and when washed with water and dried, forms **vegetable parchment.** Concentrated sulphuric acid causes cellulose to swell up and dissolve to a paste which on dilution with water gives a white precipitate of amyloid, a substance which is similar to starch and like starch gives a blue colour with iodine. Prolonged action of sulphuric acid gives dextrin.

EXPT. 34.—**Action of sulphuric acid on cellulose.** Dip a filter paper for a few seconds in sulphuric acid (2 to 1). Take it out and rinse it well. Test it with a weak solution of iodine.

Expt. 35.—**Effect of acids on cotton.** Number and wet out four 5-gram hanks of cotton. Place one hank in each of the following liquids :

No. 1 hank in 100 c.c. water.
,, 2 ,, ,, ,, + $1\frac{1}{2}$ c.c. conc. sulphuric acid.
,, 3 ,, ,, ,, + $1\frac{1}{2}$ c.c. formic acid.
,, 4 ,, ,, ,, + $1\frac{1}{2}$ grms. oxalic acid.

Raise each to the boiling point and boil for 20 minutes. Squeeze out all the hanks and allow them to dry. Test them for strength, comparing the effect of (*a*) a mineral acid with an organic acid, (*b*) a non-volatile organic acid with a volatile organic acid.

The action of nitric acid is peculiar. Dilute solutions act like dilute sulphuric acid, causing hydration and tendering. Nitric acid may also oxidise the fibre and produce oxycellulose.

Cellulose nitrates. Cold nitric acid up to 60° Tw. has no action on cellulose unless allowed to dry on the fibre. When immersed in nitric acid of 82° Tw. for 15 minutes and then dried, there is a contraction of about 24 per cent. and an increase of strength of 78 per cent. The cotton is said to be mercerised, but this must not be confused with the common method of mercerisation. The cellulose is hydrated, but at the same time **cellulose tetranitrate** is formed. The fibre has gained in affinity for direct cotton dyes and acid dyes, but not for basic dyes. Oxycellulose readily dyes with basic dyes while cotton does not, and therefore no oxycellulose has been produced in this process. Several other nitrates of cellulose are known. A mixture of 3 parts nitric acid of Sp. Gr. 1·5 with 1 part of sulphuric acid of Sp. Gr. 1·84 produces in 24 hours at a temperature of not more than 10° C. **cellulose hexanitrate**, which is known as **pyroxylin** or **gun cotton.** It is insoluble in an ether-alcohol mixture or in acetic acid. Acetone dissolves it very slowly.

Cellulose hexanitrate is given the formula $C_{12}H_{14}O_4(NO_3)_6$, showing the replacement of six OH groups in the molecule $(C_6H_{10}O_5)_2$ or $C_{12}H_{20}O_{10}$, by six NO_3 groups. A pentanitrate is also known, and the tetra- and tri-nitrates are formed together when nitric acid of moderate strength is heated with cellulose for a short time. The tetra- and tri-nitrates are soluble in ether-alcohol mixture, acetic acid, and wood spirit (methyl alcohol), and are known as **soluble pyroxylin** or collodion pyroxylin, their solution in ether-alcohol being called **collodion.** These lower nitrates may be worked up with acetone, camphor, etc., into a plastic substance which in its finished state is known as xylonite, celluloid, etc. The structure of the fibre during nitration is often unchanged, *e.g.* in gun cotton. Gun cotton will not dye with direct dyes, but has an affinity for acid dyes.

Artificial silk (" nitro " or nitrate silk). Chardonnet made use of a solution of the cellulose nitrates for the production of an artificial silk, and the method of working was improved by Lehner. A solution of soluble pyroxylin containing 10 to 12 per cent. of the pyroxylin, when acidified with dilute sulphuric acid, gives a liquid with sufficient fluidity to flow from a fine jet into water. On reaching the water a tough viscous jelly is produced which can be drawn out into a fibre. By twisting several such fibres together as in silk reeling a workable textile thread is produced. The thread is, however, extremely combustible, and is therefore denitrated by treatment with a cold ammonium sulphide solution. This artificial silk possesses a higher lustre than natural silk, but has only 70 per cent. of the strength. It is less elastic and has a smaller " covering " power than true silk. When wet, its strength is very greatly decreased.

Cotton has an affinity for tannic acid, and is able to take up 7 or 8 per cent. of its weight when allowed to steep in solutions of the acid. Mercerised cotton has a greater affinity for the acid than unmercerised cotton. Cotton, thus tanned, is capable of uniting with basic dyes (Expt. 39. 3). Weak solutions of chromic acid attack cotton very slowly.

Alkalis. Cold dilute solutions of alkalis have scarcely any action on cotton, and the same is true of hot solutions in the absence of air, but, if air be present, the cellulose is oxidised and the fibre tendered. This fact is of great importance in high-pressure kier boiling in cotton bleaching (p. 94). Concentrated solutions of alkalis have a remarkable effect on cotton. When steeped in cold solutions of caustic soda containing above 10 per cent. of the alkali, the fibre swells, becoming cylindrical, the twisted appearance is lost, and the central canal disappears. The fibre shrinks considerably, and increases in strength and in affinity for dyestuffs. The cotton is said to be mercerised. Mercerised cotton will give a deeper shade than unmercerised cotton with the same percentage of dyestuff. Cotton treated and mercerised as above has little increased lustre, but if it be stretched during the alkali treatment shrinkage is prevented, a high lustre is obtained, the yarn is stronger, and the increased affinity for dyestuffs remains. The same result is obtained if the tension be applied to the material while it is being washed with water to remove the alkali. Cotton may be mercerised either in the yarn or in the piece. After being washed with water, the material is soured (p. 95) in a fresh cold bath and again rinsed. Sea Island cotton and specially selected Egyptian cotton are very suitable for mercerisation.

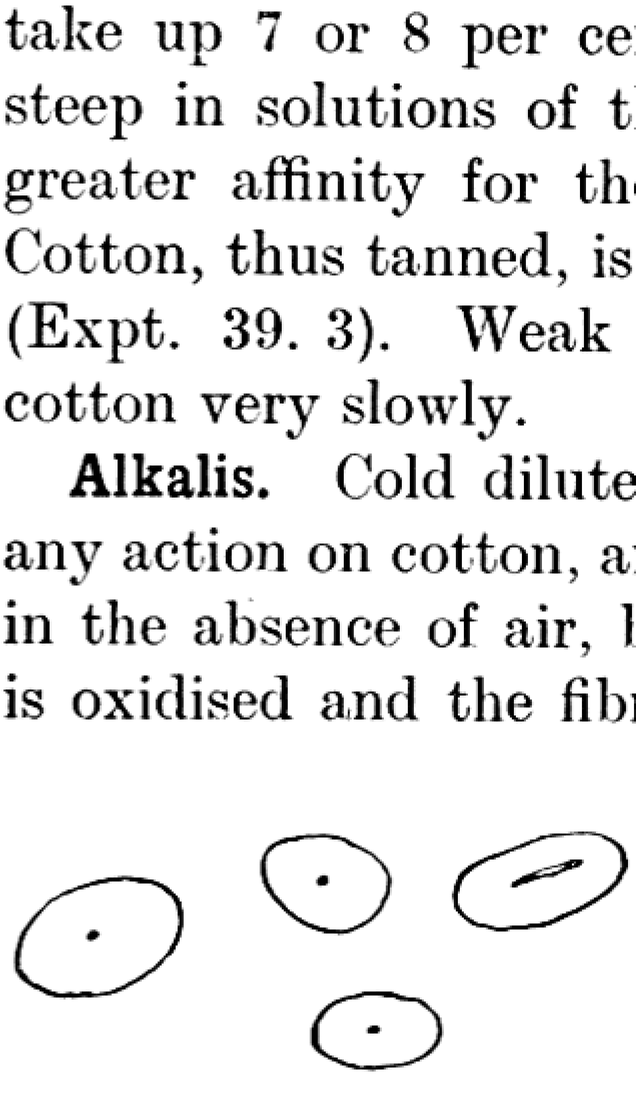


FIG. 29.—Sections of mercerised cotton fibres.

Chemical change during mercerisation. During mercerisation the cotton unites with the alkali forming a substance called alkali cellulose, but the alkali is readily removed by water leaving a cellulose hydrate. All strengths of caustic soda solution mercerise cotton, but only cold solutions of over 52° Tw. give a lustre. The alkali is recovered and used for kier boiling (p. 94).

Viscose artificial silk. The alkali cellulose formed during mercerisation combines with carbon disulphide, CS_2, to form xanthates which are soluble in water. Such solutions are used in the manufacture of artificial silk. Cellulose is soaked in a solution of caustic soda containing 15-20 per cent. NaHO and afterwards squeezed so that it retains about three times its weight of the solution. It is then treated with carbon bisulphide and forms cellulose sodium xanthate, $XNa \cdot CS_2$. This xanthate is a yellowish brown sticky dough-like substance which is soluble in water, but more readily in dilute caustic soda solution forming a very viscous solution called **viscose.** The solution is quickly coagulated by solutions of many salts or by acids, and, by forcing viscose through small holes into such coagulating solutions, an excellent artificial silk fibre can be obtained. The thread is rendered extremely lustrous by after-treatment, and is considered to be the best artificial thread at the present time. Like other artificial silks it loses considerably in strength when wet, but great improvements have been made in this respect in the last two or three years. Viscose silk may be dyed at the boil, but cuprammonium silks (p. 93) and nitro-silks cannot. Viscose behaves like cotton towards most reagents and dyestuffs but is more readily attacked by bleaching agents. Viscose is also used for producing satin-striped effects in wall papers.

EXPT. 36.—**The effect of alkalis on cotton.** Number and wet out five 5-gram cotton hanks. Treat as follows:

No. 1 hank in 100 c.c. water.
,, 2 ,, ,, ,, +2 grms. caustic soda.
,, 3 ,, ,, ,, +2 grms. soda ash.
,, 4 ,, ,, ,, +2grms. ammonium carbonate.

Raise the temperature of the baths to the boiling point and boil for 20 minutes. Rinse the hanks well, but do not dry them. No changes will be observed (compare wool).

Mercerisation. Measure the length of No. 5 hank, and then stir it in a solution of caustic soda of 52° Tw. for five minutes. Take it out, rinse it in cold water, then in water containing a little acetic acid, and again in water. Again measure the length, and calculate the percentage shrinkage. The original and final lengths may be taken in each case when the material is dry, but as No. 5 hank is to be dyed immediately, the wet lengths are taken.

Dye Nos. 1, 2, 3, and 5 in separate pots, each containing 100 c.c. water + 1 per cent. benzopurpurin. Raise them slowly to the boiling point and boil them for 20 minutes. Compare for depth of shade and strength.

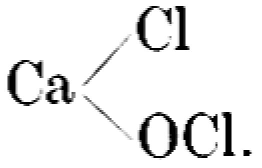
Chlorine and hypochlorites. Weak solutions of hypochlorites have only a slight effect on cellulose and may be used safely for bleaching cotton. Stronger solutions produce an appreciable quantity of oxycellulose. The presence of oxycellulose may be shown by immersing the material in a dilute solution (1 per cent.) of methylene blue. The oxycellulose will be dyed. Oxycellulose is soluble in alkalis.

Hypochlorous acid, $HOCl$, is known only in weak solution. When chlorine is passed into a cold solution of caustic soda or caustic potash, a mixture of a chloride and hypochlorite is formed.

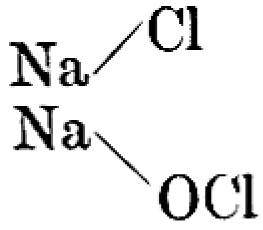
Caustic soda + Chlorine → Sodium chloride + Sodium hypochlorite

$$2NaHO + Cl_2 = NaCl + NaOCl + H_2O.$$

When chlorine is passed into slaked lime, bleaching powder is formed. Bleaching powder consists chiefly of calcium chlor-hypochlorite and unconverted slaked lime. Calcium chlor-hypochlorite has the structural formula



The calcium atom is bivalent, and one of its affinities is satisfied by the chlorine atom and the other by the hypochlorous acid radicle. Compare this formula with that of the mixture obtained by passing chlorine into caustic soda, thus



From the formula $CaOCl_2$ the percentage of chlorine available for bleaching can be calculated.

$$\underbrace{\underset{40+16+71}{CaOCl_2}}_{127} + H_2SO_4 = CaSO_4 + H_2O + \underbrace{\underset{2 \times 35 \cdot 5}{Cl_2}}_{71}$$

Pure calcium chlor-hypochlorite should give $\frac{71}{127} \times 100 =$ nearly 56 per cent. of chlorine, but bleaching powder yields only 35 per cent. Bleaching powder is decomposed by the carbon dioxide of the air and chlorine is liberated. It should therefore be kept in air-tight vessels. Bleaching powder is not completely soluble in water and a clear solution is obtained by settling. The solution is alkaline owing to the presence of lime. If a clear solution be not used for bleaching, tendering is liable to occur where the small particles of lime stick to the cotton, owing to the formation of oxycellulose, and this may lead to spottiness in dyeing. A clear solution of sodium chloride and sodium hypochlorite can be obtained from bleaching powder by decomposing it with a solution of sodium carbonate.

Bleaching powder + Soda ash → Calcium carbonate + Common salt + Sodium hypochlorite

$$CaOCl_2 + Na_2CO_3 = CaCO_3 + NaCl + NaOCl.$$

The mixture after being stirred is allowed to settle and the clear liquid siphoned off. **Electrolytic bleach** is prepared by electrolysing a cold solution of common salt and stirring the liquid so that the chlorine liberated at the anode is brought into contact with the caustic soda formed at the cathode, when a reaction takes place resulting in the production of a solution of chloride and hypochlorite. This solution is preferred to bleaching powder for many purposes, but is slightly more expensive. It must be prepared on the spot owing to cost of carriage. Its possible use, however, keeps the price of bleaching powder under control.

Oxidising agents. Neutral solutions of permanganates have very little effect on cellulose, but alkaline solutions rapidly oxidise it.

Ammoniacal cupric oxide. This solution may be prepared in several ways, two of which are given :

1. To a solution of copper sulphate add ammonium chloride solution and then excess of sodium hydroxide. Filter the solution through a cloth filter, wash the residue well, and dissolve it in ammonia of Sp. Gr. 0·09.

2. Place thin sheet copper in a bottle and cover it with strong ammonia. Bubble oxygen slowly through the solution for some hours.

This ammoniacal solution, often known as **Schweitzer's reagent**, should contain 10 to 15 per cent. of ammonia and 2 to 2½ per cent. of copper oxide, CuO. When cotton is placed in such a solution, the fibres swell up and finally dissolve.

EXPT. 37.—**Action of Schweitzer's reagent on cotton.** Place two or three cotton fibres on a microscope slide, moisten them with the reagent, and examine the action under the microscope. Draw sketches of the appearance of the cotton.

Cuprammonium silk. A solution of cellulose in ammoniacal copper oxide, containing 8 per cent. of cellulose, when forced through fine holes into dilute acid (15 to 20 per cent. strength) or alkali, is coagulated and gives an artificial silk known as **Glanzstoff.** Thiele used a similar liquid, but forced it into a very dilute solution and obtained a sticky thread which could be pulled out and twisted. In this way a finer, softer, more glossy, and stronger thread was obtained than by the original Glanzstoff process.

Willesden cloth. When cotton cloth is passed through ammoniacal copper oxide, the surfaces of the threads are swollen and gelatinised, and when dried, the fibres are more compact and the material water resistant. The cloth acquires a bright green colour, due to the copper compound. Copper compounds are preservatives against mildew. The cloth while gelatinised may be pressed so as to give a still more compact cloth known as **Willesden cloth.**

Acetyl cellulose. Cellulose is acted upon by a mixture of acetic anhydride and acetic acid in the presence of a small quantity of concentrated sulphuric acid or zinc chloride giving **acetyl cellulose.** It is soluble in various organic solvents and insoluble in water, and among other uses is made into an artificial silk (acetate silk). Its solution in symmetrical tetrachlorethane is used as a dope for aeroplane fabrics.

Salts. Cotton differs from wool and silk in that it has little affinity for the metallic oxides and will not decompose such salts as bichrome, alum, etc. It will, however, absorb small quantities of the oxides from basic compounds of aluminium, copper, chromium, etc. Sodium stannate is absorbed to an appreciable extent by cotton. Acid salts are liable to tender cotton, and salts such as magnesium chloride and aluminium chloride, which decompose when heated, liberating hydrogen chloride (see carbonisation, p. 64), must be carefully used. Magnesium chloride is largely used in cotton finishing, and tendering may occur if the cloth be subjected to high temperatures, as in hot pressing.

Fire-proof cloth. Many salts have been used in finishing flannelette to render it non-inflammable. Sodium tungstate and borax, which have been so used, are soluble in water and therefore readily washed out. Cloth, soaked in a solution of sodium stannate, squeezed, dried, treated with a solution of ammonium sulphate, dried, and then washed to remove the sodium sulphate formed, is rendered non-inflammable owing to the fixation in the cloth of stannic oxide. The stannic oxide, SnO_2, being insoluble, gives a permanent result and at the same time leaves the material soft.

Cotton bleaching. The bleaching of cotton may be divided into two processes, the first having for its object the destruction of waxy and other impurities in the cotton. At the same time it removes almost all the colouring matter. The second process bleaches the remainder of the colour. The first process is not a bleaching action in the sense in which the term bleaching has previously been used, but as it removes the major portion of the colouring matter it is evidently an important part of the bleaching process. It consists of boiling the material with a solution of an alkali, either at ordinary pressures or in boilers (kiers) under low or high pressure.

The second process consists of steeping the material in a weak solution of bleaching powder (**chemicking**), removing excess of the solution by a slight rinsing, and then

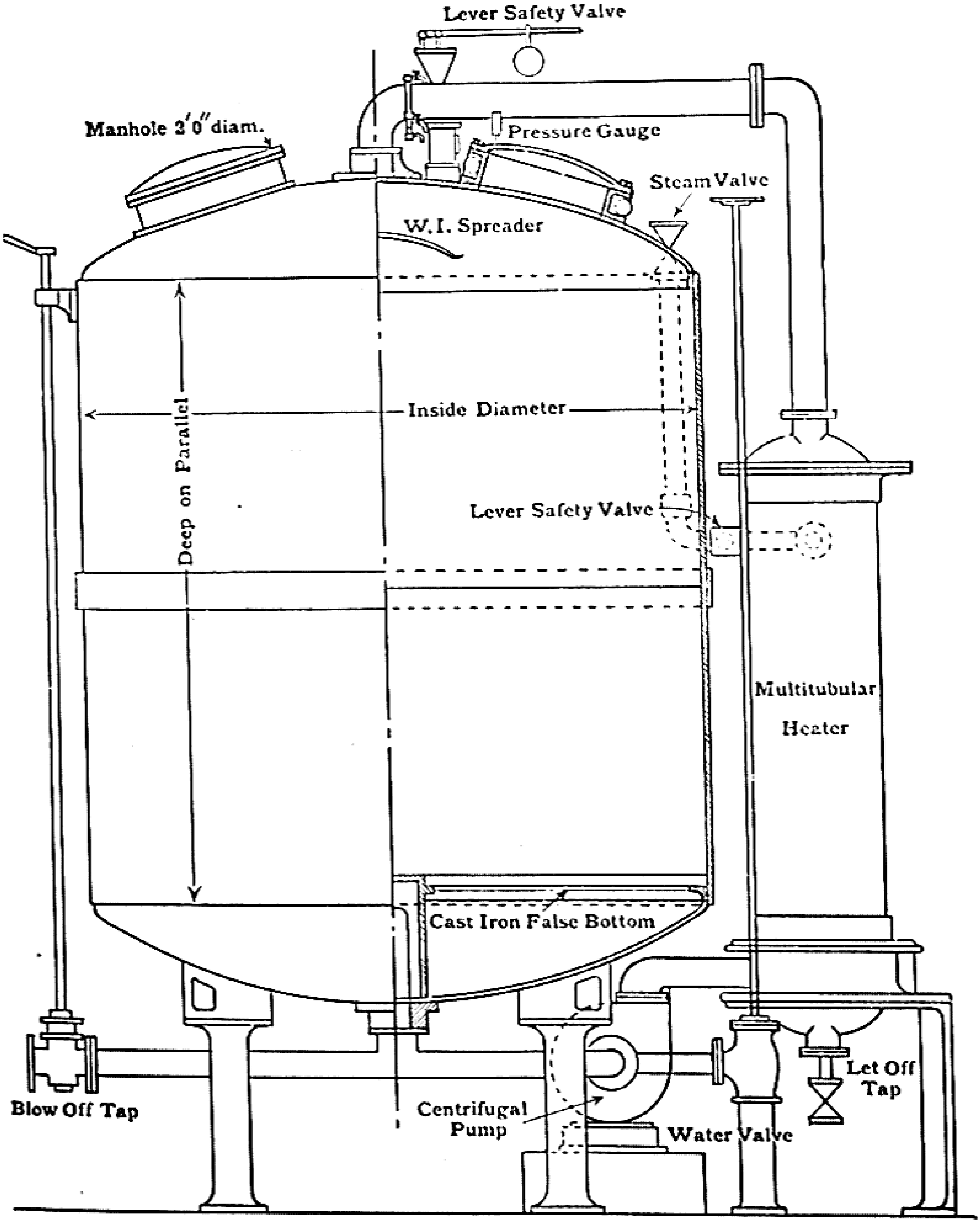


FIG. 30.—High pressure circulating kier (Mather and Platt, Ltd.).

treating with a weak acid solution (**souring**). The acid liberates chlorine from the bleaching powder, and this, in presence of water, oxidises the colouring matter of the cotton.

$$\overset{\text{Bleaching powder}}{\mathrm{CaOCl_2}} \overset{+}{+} \overset{\text{acid}}{2\mathrm{HCl}} \overset{\rightarrow}{=} \mathrm{CaCl_2} + \mathrm{H_2O} + \overset{\text{chlorine}}{\mathrm{Cl_2}},$$

$$\mathrm{Cl_2} + \mathrm{H_2O} + \text{colour} \rightarrow 2\mathrm{HCl} + \text{colourless substance.}$$

The process is one of oxidation and is permanent. There are many ways of carrying out the two processes according to the after-requirements of the material, and only a brief indication of their application will be given. Cotton may be bleached loose, as sliver, as yarn, in cops or cheeses, or in the piece.

Bleaching of loose cotton. Loose cotton is only bleached when required for cotton wool, in which case it is given a steeping in a warm solution of caustic soda, 2° Tw., or soda ash, rinsed, steeped in bleaching powder solution, 1 to 1½° Tw., rinsed, soured in sulphuric acid, 1 to 1½° Tw., and then thoroughly washed to remove acid. Care must be taken to prevent matting. Cotton sliver is bleached in special machines, where it is first boiled with soda ash or caustic soda, then rinsed, chemicked, rinsed, soured and washed.

Cops and cheeses. These are packed into baskets or hemp bags and placed in the kier and boiled with alkali. An Obermaier machine may be used. Sodium hypochlorite is preferred to bleaching powder for chemicking. If a full bleach is not required, the boiling with alkali may be omitted.

Yarns. Hanks and warps are made into chain form and treated as above.

Pieces. The bleaching of cotton piece goods may differ from the above owing to the presence in the material of starches, waxes, soaps, etc., which have been used in the preparation (**sizing**) of the yarn for weaving. Starches may be removed with the help of ferments by steeping the pieces in water containing malt or Diastafor (a malt extract). Magnesium chloride, zinc chloride, and similar substances, which may cause tendering when the material is singed, are removed by washing. Waxes and oils are removed in the kier boils. Paraffin wax is difficult to remove. An example of calico bleaching is given below.

Stamping and stitching. The pieces to be bleached are stamped with letters or numbers, gas tar being generally used. The pieces are then stitched end to end, thus forming a long piece which is convenient to handle and pass from one part of the works to another.

Singeing and gassing. The nap is next removed, if necessary, by running the cloth quickly across the surface of a red-hot plate **(plate singeing)** or over a row of Bunsen flames (**gas singeing or gassing**). The cloth should immediately be passed into water or steam to extinguish any sparks. The material is then steeped, washed, or otherwise treated to remove starches and soluble salts.

Bowking. The material is then passed through milk of lime and packed into a kier by tramping down. Here the material, having taken with it some of the lime, is covered with water and heated in the closed kier with high-pressure steam. The lime destroys the waxy matter, etc., and is cheaper than caustic soda. This treatment with lime is called the **lime boil** or **bowking**. After being sufficiently treated with lime, it is washed and soured. The souring is done with a weak solution of hydrochloric acid or sulphuric acid, the former being preferred because the calcium chloride produced is much more soluble than calcium sulphate. Hydrochloric acid is, however, more expensive. After souring, the material is washed.

Lye, or ley-boil. The material is now treated in kiers with a weak solution (1 to 2 per cent.) of soda ash or a mixture of soda ash and caustic soda. If ordinary or low pressure is used, the process requires twelve hours, which is reduced to four hours by high pressure. The ley-boil may be followed by a **resin boil**, which is a boiling with a resin soap, and removes certain substances which would attract colour in the dye bath. A second soda ash boil is given to remove undissolved resin and fatty matters. The material is now **chemicked**, **washed**, **soured**, and **washed** as before.

Anti-chloring. To remove chlorine left after bleaching, the material is passed into an anti-chlor, which consists of a weak solution of sodium sulphite, sodium bisulphite, or sodium thiosulphate (hypo).

$$\overset{\text{Sulphite}}{NaHSO_3} \overset{\text{+Chlorine}}{+Cl_2} + H_2O \overset{\rightarrow}{=} \overset{\text{Sulphate}}{NaHSO_4} \overset{\text{+Hydrochloric acid}}{+2HCl},$$

$$\underset{\text{“hypo.”}}{2Na_2S_2O_3} + Cl_2 = \underset{\text{sodium tetrathionate.}}{Na_2S_4O_6} + 2NaCl,$$

Sulphur dioxide will also act as an anti-chlor.

$$\overset{\text{Sulphur dioxide}}{SO_2} \overset{\text{+ Water}}{+2H_2O} \overset{\text{+Chlorine}}{+\ Cl_2} \overset{\rightarrow}{=} \overset{\text{Sulphuric acid}}{H_2SO_4} \overset{\text{+Hydrochloric acid}}{+\ 2HCl}.$$

The material is again washed after this treatment.

Turkey red bleach. It should be remembered that pieces for different purposes do not require the same bleaching, and to illustrate this it may be mentioned that for Turkey red dyeing it is sufficient to treat as follows: (1) wash, (2) boil with water for two hours and wash, (3) lye-boil with caustic soda and wash, (4) repeat lye-boil, (5) sour, wash, and dry.

Blueing. When the piece is to remain white, *i.e.* not to be dyed afterwards, it is generally blued.

Cotton may also be bleached with hydrogen peroxide, potassium permanganate, sodium perborate, ozone, etc., after the kier boils, but these reagents offer no special advantages and are more expensive than the hypochlorites.

Expt. 38.—**Cotton bleaching.**

Lye-boil. Boil out three unbleached cotton hanks with 3 grms. of caustic soda in 150 c.c. of water for half an hour, wash them well, and use them in the following experiments. Unbleached mercerised cotton may be used for the experiments and the lye-boil omitted.

1. *Peroxide bleach.* Place one lye-boiled cotton hank in 100 c.c. water containing 10 c.c. hydrogen peroxide (20 vols.) +0·5 c.c. of dilute ammonia. Raise it slowly to 50° C. and leave it overnight. Wash the hank well.

2. *Permanganate bleach.* Place one lye-boiled cotton hank in 100 c.c. water containing 0·1 grm. of potassium permanganate and leave it for 30 minutes. Wash it and keep a sample for mounting. Treat the remainder in 100 c.c. water containing 2·5 c.c. of commercial bisulphite solution (71° Tw.), or 1 grm. of $NaHSO_3$, +2 c.c. sulphuric acid till the brown colour disappears. Wash it well.

3. *Hypochlorite bleach.* Make a bleaching powder solution, as in Expt. 20, for wool. Place a lye-boiled cotton hank in the solution and allow it to stand overnight. Squeeze the hank and take a sample. Rinse the remainder slightly and sour it with cold dilute sulphuric acid, 1° Tw., for 15 minutes. Wash it well and keep a sample. Antichlor what is left of the hank by immersing it for 15 minutes in 100 c.c. cold water containing 0·5 grm. of "hypo." Wash and dry the hank.

4. *Tinting or blueing.* Place a wet out unbleached cotton hank in 100 c.c. water containing not more than 0·005 per cent. of methyl violet. Treat it for 15 mins. lukewarm, and then rinse it and dry it.

Dyes. Cotton dyes directly with substantive dyes (salt dyes or direct cotton dyes), but not with acid or basic dyes. Basic dyes are dyed on tannin mordanted cotton. Many tannin substances are available, and their value is best determined by carrying out comparative mordanting and dyeing tests. Vat dyes (indigo, chloranthrenes, indanthrenes, etc.) are fixed on the cotton in the reduced condition and afterwards oxidised. Sulphur dyes (cross dyes, immedial, thiogene, etc., dyes) are dissolved in a solution of sodium sulphide which reduces them. The material after treatment in this solution is exposed to the air to oxidise the reduced dye.

Expt. 39.—**Behaviour of cotton towards dyes.** Number and wet out nine 5-gram hanks of cotton.

1. *Acid dyes.* Place No. 1 hank in

100 c.c. water + 1 % acid magenta or other acid dye.

Raise the bath to boiling point and boil for three-quarters of an hour. Rinse the hank well and dry it.

2. *Salt dyes.* Place No. 2 hank in

100 c.c. water + 10 % Glauber's salt + 1 % benzopurpurin or other salt dye.

Raise the bath to boiling point and boil for three-quarters of an hour. Rinse the hank well and dry it.

3. *Basic dyes.* Place No. 3 hank in

100 c.c. water + 10 % methyl violet or other basic dye.

Raise the bath to boiling point and boil for three-quarters of an hour. Rinse the hank well and dry it.

Place No. 4 hank in 100 c.c. water containing 0·2 gram of tannic acid, raise the bath to boiling point and allow it to stand overnight. Rinse the hank, dye it as for No. 3 hank, rinse it well, and dry it.

4. *Mordant dyes.* Mordant No. 5 hank by immersing for 10 minutes in 100 c.c. water containing 1 gram ferric chloride, $FeCl_3$. Squeeze the hank and immerse it in 100 c.c. water containing 1 gram of soda ash. This will precipitate ferric hydroxide in the material.

Ferric chloride + Soda ash solution → Ferric hydroxide

$$2FeCl_3 + 3Na_2CO_3 + 3H_2O = 2Fe(OH)_3 + 6NaCl + 3CO_2.$$

Dye No. 5 and No. 6 in separate baths each containing 100 c.c. water + 2 per cent. alizarine. Raise the baths to boiling point and boil for three-quarters of an hour. Rinse the hanks well and take samples. Wash the remainders of each hank in soap and water, and dry them.

Note.—The student may try mordanting the cotton by precipitating other metallic oxides in this way or by soaking the material in acetates of the metals, drying them and heating to drive off acetic acid. Reference should be made to text-books on dyeing.

5. *Vat dyes* (indigo, etc.). Prepare an indigo vat as for wool, Expt. 21. 5, and dye No. 7 and No. 8 hanks, giving one several dips and the other one dip equal in length of time to the several dips of the other. Allow the hanks to oxidise as before and wash them well. Other vat dyes may be tried using the recipes given in the dye catalogues.

6. *Sulphur dyes.* Prepare a vat as follows. Dissolve 0·25 gram of immedial blue C. in 100 c.c. water containing 0·25 gram of sodium sulphide + 0·1 gram caustic soda + 0·2 gram common salt or Glauber's salt (anhydrous). Dye No. 9 hank for one hour at the boiling point, squeeze it, and allow it to oxidise. For the dyeing of other sulphur dyes consult the dye catalogues for the quantities of the additions to the bath.

EXPT. 40.—**Detection of cotton in a union of cloth and wool.** Place a small piece of the union in a solution of acid magenta (or other acid dye which does not stain cotton). Boil the material for a few minutes, take it out, and rinse it. The cotton threads will remain white.

Mildew. Cotton is more liable to mildew than wool and may be protected by the use of antiseptics. Phenol (carbolic acid) is not much use owing to its volatile character. Salicylic acid is an excellent antiseptic and is non-volatile. Zinc chloride is very commonly used in the finishing of cotton fabrics as a softening agent and as a preservative against mildew.

QUESTIONS VII.

1. Give a list of bleaching agents used in textile work, and state which you would use for (*a*) wool, (*b*) cotton, (*c*) silk. Give reasons for your selection.

2. Describe the process of mercerisation, and give the effects of the process on the properties of cotton.

3. What is the effect of sulphuric acid of varying strengths and temperatures on cotton ?

4. Upon what principle is the process of carbonisation based ? How is the process carried out ?

5. How does the chemical composition of wool differ from that of silk ? How would you show the presence of cotton threads in a mixture of wool, cotton, and silk ?

6. Describe the process by which cotton piece goods are bleached.

7. What is the object of blueing, and how is it carried out ?

8. Point out the differences in the processes of mordanting wool and cotton.

9. Write an essay on the action of nitric acid on cotton.

10. Give the methods of preparation of three forms of artificial silk.

11. Describe the behaviour of cotton towards dyes. How would you dye cotton with alizarine ?

12. Define the following processes: chemicking, souring, antichloring—giving the chemical actions which take place during each process.

13. What is ammoniacal copper oxide, and how may it be prepared ? To what uses is it put ?

14. What is (*a*) bleaching powder, (*b*) electrolytic bleach, (*c*) hydrocellulose, (*d*) vegetable parchment ?

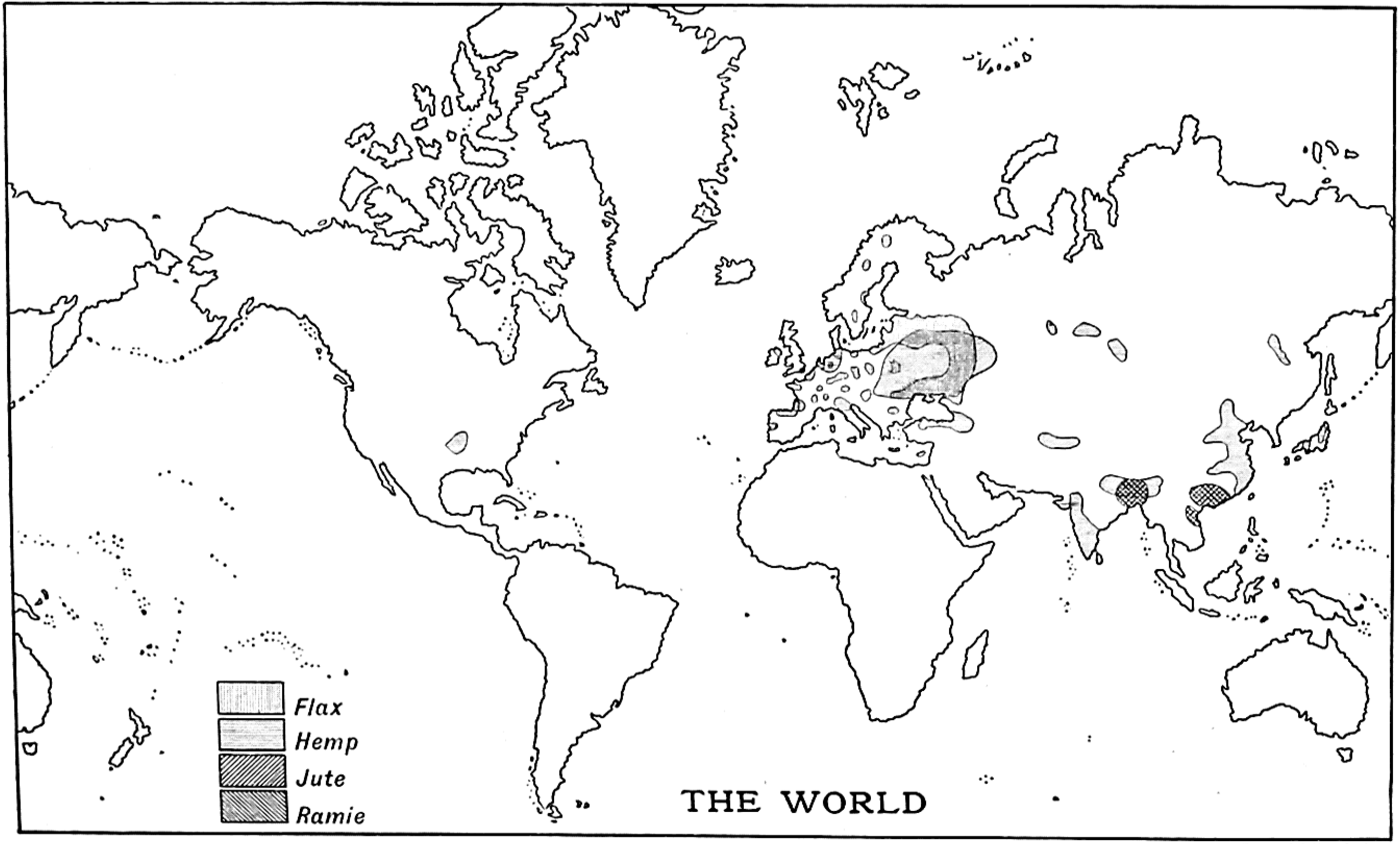
CHAPTER VIII

OTHER TEXTILE FIBRES

Linen. Linen is a **bast fibre** obtained from the flax plant, *Linum usitatissimum.* The flax plant, which is an annual, is cultivated principally in France, Holland, Belgium, Russia, the United States, and Canada. It grows to a height of 40 inches and has a slender stem. When ripe the plants are either pulled or cut, and are drawn through the prongs of upright combs to remove the leaves and seeds (**rippling**). The seeds, by pressure, yield the valuable linseed oil, and the oil cake left is an important cattle food. The best **seed flax** is grown in tropical and subtropical countries.

Separation of the bast fibres. The stems, after rippling, are tied together in bundles, and are then subjected to the process of **retting** with the object of removing the bark and loosening the bast fibres beneath. The bast fibres are in groups surrounded by an intercellular substance which is rendered soluble by retting.

Retting may be carried out in several ways: (*a*) The flax is allowed to remain in stagnant water for from four to fifteen days, the bundles being weighted to keep them under the surface. Fermentation sets in but is not allowed to proceed too far. When a sample, taken out of the water, shows that the bast fibres are loose, the action is stopped. (*b*) The flax is spread over fields for



Emery Walker Ltd. sc.

from fifteen to thirty-five days. This is called **dew retting.** (*c*) The flax is retted in running streams. (*d*) A preliminary retting in water is completed by dew retting. These are practically the only processes used, though warm water retting, hot water and high-pressure steam retting, and various chemical agents, have been tried.

Breaking, scutching, and heckling. After retting, the stalks are hammered by hand or passed between fluted rollers in order to break the woody core (**breaking**). This is followed by scutching, which consists of striking the stalks with a wood knife (by hand or machinery) to remove the adhering wood, and then the material is combed (**hackling** or **heckling**) to remove the remainder of the wood and to make the fibres parallel. The short and tangled fibres removed in this process are known as **tow** and the more valuable longer fibres as **line.** The colour of the line varies from the yellowish buff of the Belgian to the green grey of the Russian. The colour depends to a certain extent on the method of retting. The best flax

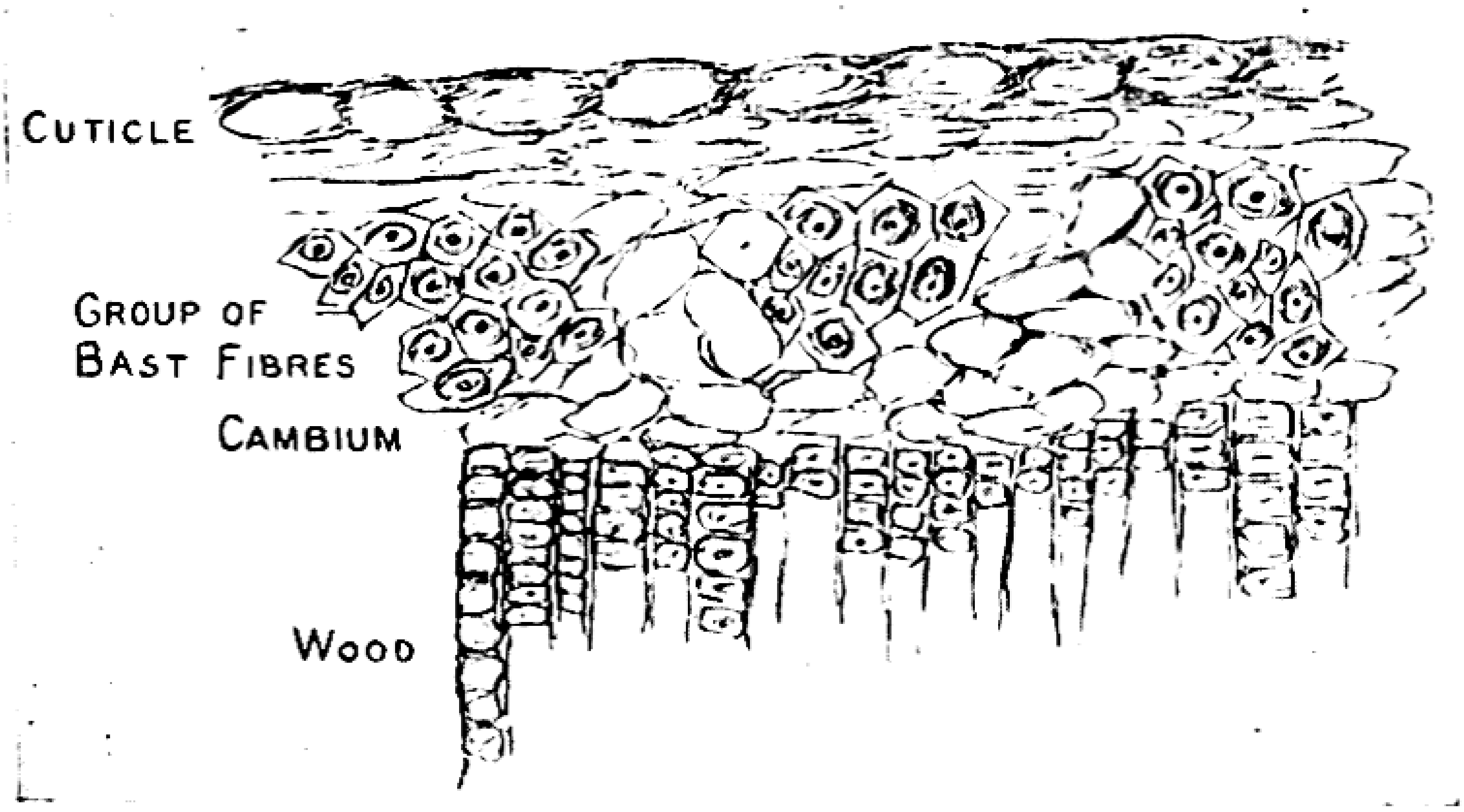


FIG. 31.—Enlarged cross-section of flax stem, showing bast fibres.

is obtained from Courtrai and is retted in the slowly moving River Lys. The weight of fibre obtained varies roughly from 6 to 10 per cent. of the weight of the dried flax.

Microscopic appearance. The fibre is of regular thickness, pointed at the ends, and shows transverse cracks or knot-like swellings known as nodes. A cross-section shows that the fibre is made up of a large number of polygonal cells.

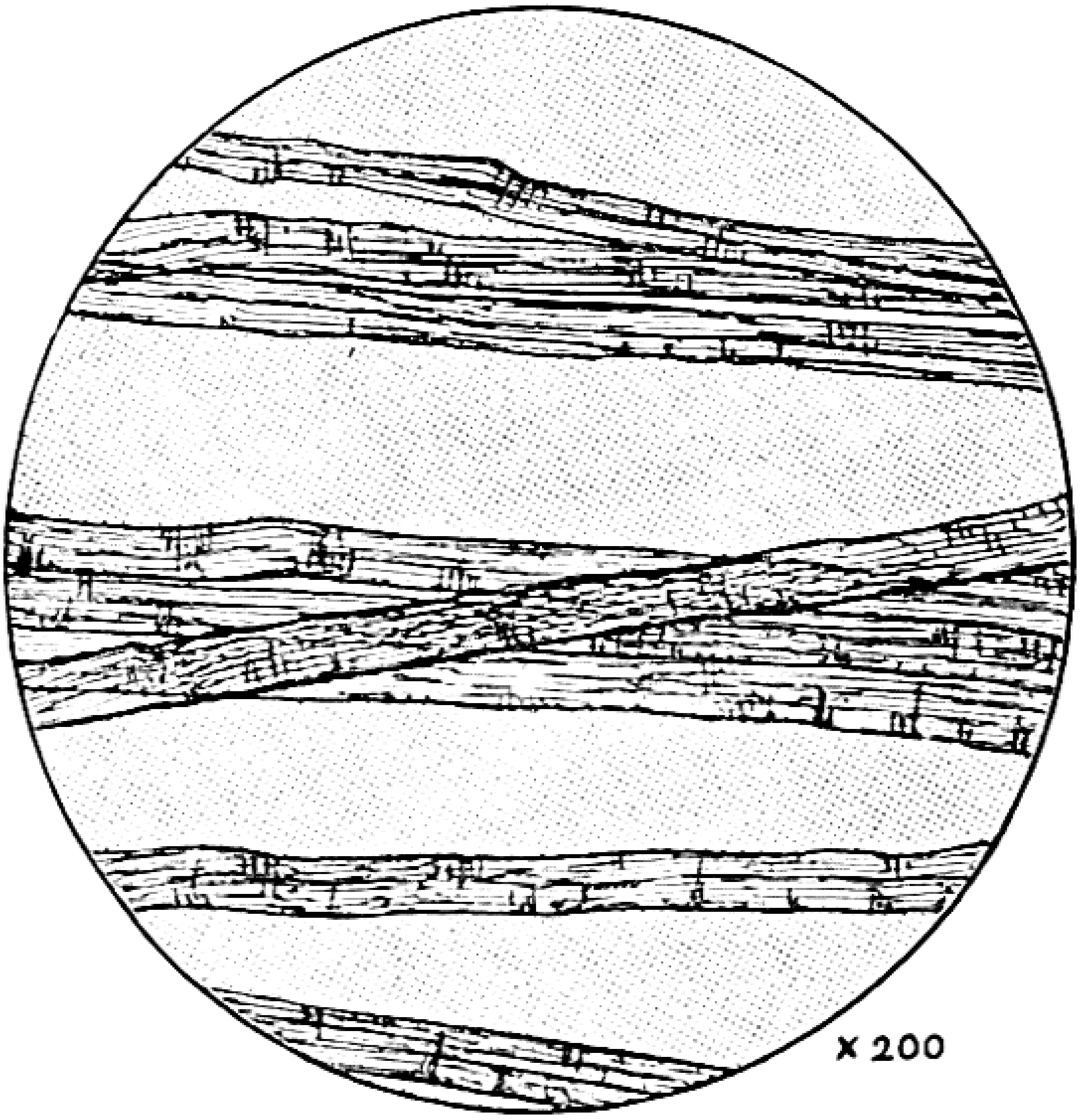


FIG. 32.—Microscopic appearance of flax fibres.

Physical properties of linen. The length of the fibre varies from a few inches to several feet, depending upon the care taken in separating the fibres. Good flax should average 20 inches and be free from short fibres. The individual cells vary from 2·5 to 3·75 cm. in length and from 0·012 to 0·030 mm. in diameter. The tensile strength of linen is much superior to cotton, and the best qualities of linen have a good lustre. Linen is soft and hygroscopic, absorbing up to 20 per cent. of moisture. It is a better conductor of heat, is less elastic, more durable, and more brittle than cotton. When a linen thread is broken the ends remain straight, but those of cotton curl up.

Composition of linen. Like cotton the principal constituent is cellulose, but it contains intercellular pectic matter as an impurity. Analysis gives

	Per cent.
Water	8 to 10
Fat and wax	2 ,, 5
Cellulose	70 ,, 80
Humous and pectic matter	6 ,, 15
Ash	1

Chemical reactions of linen. Linen, being mainly cellulose, behaves to chemical reagents like cotton, but is more resistant. It is more difficult to bleach, and the bleaching must be carried out slowly or the fibre is liable to break down. Towards water, acids, alkalis, dyes, and mordants, linen is less reactive than cotton, and is therefore slightly more difficult to dye. Ammoniacal copper oxide causes the fibre to swell up and the central canal to assume a vermiform appearance.

Linen bleaching. Linen contains a greater amount of impurities than cotton. These impurities are mainly removed by boiling with caustic soda, but as the strength of the linen fibre is more readily attacked by caustic soda and bleaching powder than that of cotton, greater care must be taken, and therefore weaker solutions are used. **Grassing**, *i.e.* exposing the material in fields to the action of light, air, and moisture, may be, but seldom is, used alone. The following may be taken as an example of the methods used for linen bleaching. As in the case of cotton pieces, number and stitch the pieces together, pass them through lime water and boil them for 8 to 12 hours in a low-pressure kier. Wash and drain the material, sour it with hydrochloric acid (1 to $1\frac{1}{2}$° Tw.), and again wash it well. Then boil it in a low-pressure kier with a weak solution of soda ash and caustic soda. Repeat this lye-boil with a weaker solution. Grass the material for two days. Then treat it with weak hypochlorite solution ($\frac{1}{2}$° Tw.), rinse it, sour it with sulphuric acid (1° Tw.), wash it thoroughly, and grass it again. Repeat the treatment—the hypochlorite, followed by grassing—until the material is sufficiently bleached.

EXPT. 41.—**To distinguish cotton from linen.** (1) Treat the material with a 1 per cent. alcoholic solution of magenta (Fuchsine) for a few minutes, and then wash it in a weak solution of ammonia. Both fibres are first coloured rose, but, after the washing with ammonia, the cotton becomes colourless and the linen remains coloured. (2) Place a piece of the material in a warm alcoholic solution of cyanine and leave it for a few minutes. Rinse it and treat it with dilute sulphuric acid. Cotton becomes colourless and linen is distinctly blue. Wash the piece free from acid and place it in ammonia solution. The colour of the linen becomes darker. (3) Wet out a small piece of the material and dye it in a warm solution of methylene blue until a dark shade is obtained. Wash it well. Cotton becomes almost colourless, but the linen remains distinctly blue.

Trials similar to those given for cotton, *e.g.* Expts. 35 to 39, may be carried out with linen and with the other fibres mentioned in this chapter.

Hemp. This is another bast fibre, and is obtained from the *Cannabis sativa*, which thrives better in warmer and moister climates than does flax. The chief supply comes from Russia and the Philippines. The plant is an annual, growing to a height of 6 to 8 feet, and is ready in three to four months after planting. The seeds yield a green-looking hemp seed oil, which is used for the making of soap, artists' colours, and varnishes. In India, hemp is largely grown for its narcotic products. The fibre is obtained in a manner similar to that for linen, *i.e.* by **retting**, **breaking**, **crushing** (to render soft and supple), **cutting** (to make the fibres of convenient length), and **hackling.**

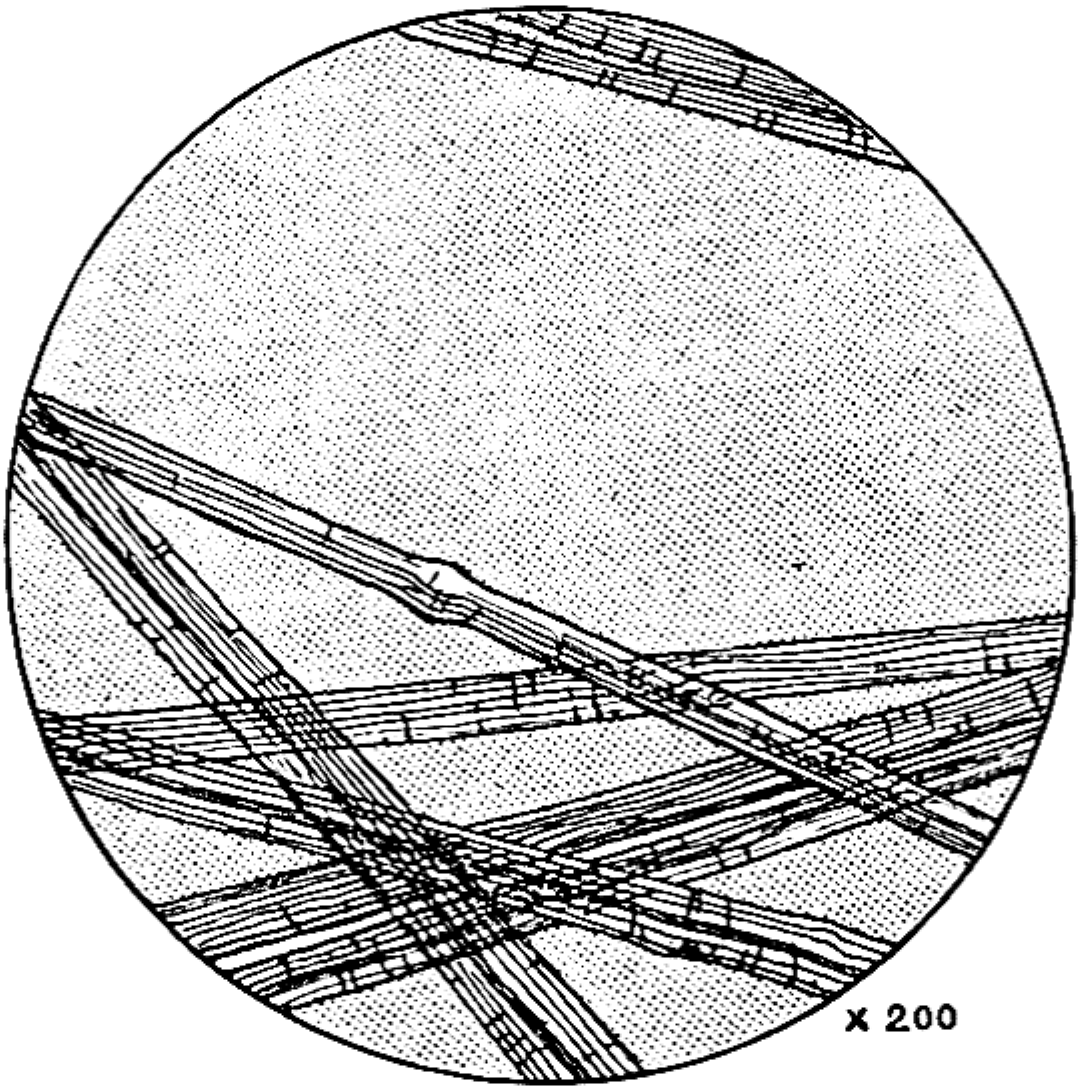


FIG. 33.—Microscopic appearance of hemp fibres.

Microscopic appearance. The individual cells are somewhat similar to those of flax, but the lumen is large and the fibre less regular. They show frequent joints or nodes, and the blunted ends of the fibres are characteristic.

Physical properties. Hemp is slightly more hygroscopic than either cotton or linen. It is strong, durable, and not rotted by water, and is therefore used for manufacture of ropes and twine, sailcloth, packsheets, etc.

Composition of hemp. Hemp consists of impure cellulose, as shown by the following analysis of Italian hemp:

	Per cent.
Cellulose	76·9
Intercellular and pectic matter	9·3
Water extract	3·5
Fat and wax	·6
Moisture	8·9
Ash	·8

Chemical reactions of hemp. Hemp gives a green colour with sulphuric acid and iodine, and thus differs from cotton and linen, which give a blue colour. This green colour is due to the blue colour given by the cellulose being modified by the yellow colour produced by the reagent with the ligno-cellulose or woody matter present in the fibre. Aniline sulphate gives a yellow colour with hemp, but not with cotton or linen. Nitric acid colours hemp yellow. Ammoniacal copper oxide causes the fibre to swell, but does not dissolve it.

Bleaching of hemp. Hemp is rarely thoroughly bleached, but is often given a mild bleach by steeping in sodium silicate, then boiling with water, rinsing, chemicking, souring, and antichloring. For a full bleach the operations are repeated. Grassing may also be used.

Varieties of hemp. The name hemp is given to a large number of bast fibres more or less similar to common hemp. Thus we have **Sunn hemp** (*Crotalaria juncea*), **Sisal hemp** (*Agave rigida*), **New Zealand hemp** or **flax** (*Phornium tenax*), **Manila hemp** (*Musa textilis*). Manila hemp makes the best ropes, and is also used for bags and rough upholstery.

Jute. Jute is also a bast fibre from various species of the plant *Corchorus*. The chief source is the Jews' mallow or jute plant (*Corchorus capsulari*), an annual which grows best in the warm damp Asiatic countries, especially India (Bengal). The plant grows to a height of 17 feet, and the prepared fibre obtained by retting has a length varying from 7 feet in the poorer qualities to 13 or 14 feet in the best qualities. Jute is principally used for bags and wrapping cloths.

Microscopic appearance. The individual cells vary in length from 0·5 cm. to 2 cm. and from 0·020 to 0·025 mm. in diameter. They are smooth in appearance without longitudinal or transverse markings, and the central canal is prominent and shows characteristic constrictions. A cross-section shows that the cells are polygonal.

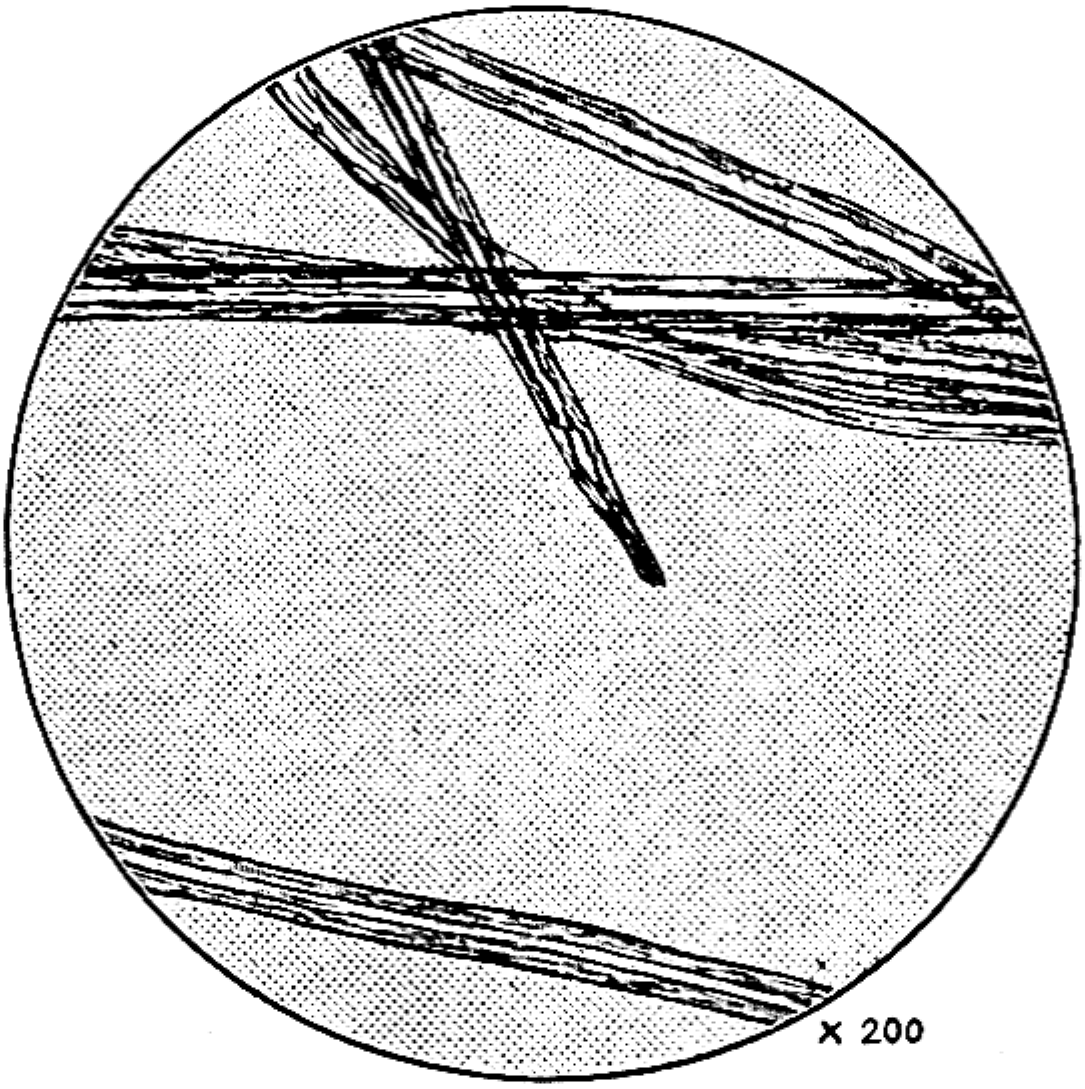


FIG. 34.—Microscopic appearance of jute fibres.

Physical properties. The best kinds of jute are pale yellow or silver grey. Jute is moderately lustrous and has great tensile strength, but its resistance to mechanical wear is small. It is hygroscopic and takes up 24 per cent. of moisture.

Composition of jute. Jute consists principally of lignocellulose, and contains up to 75 per cent. of pure cellulose, which can be obtained by repeated treatment of the fibre with chlorine. The lignin may also be removed by treatment with sodium bisulphite, as in the manufacture of wood pulp. An analysis gave

	Per cent.
Cellulose	63·9
Pectic matters, etc.	24·1
Fat and wax	·4
Water extract	1·0
Moisture	9·9
Ash	·7

Chemical reactions of jute. Jute is more readily attacked by alkalis and acids than other vegetable fibres, and with acids forms soluble substances. Alkalis leave an insoluble cellulose and produce soluble bodies similar to the tannins. Jute behaves like tannin mordanted cotton, and dyes direct with basic dyes. Chlorine and strong solutions of bleaching powder form chlorinated compounds and weaken the fibre. Iodine and sulphuric acid colour the fibre yellow, and an alcoholic solution of phlorglucinol with hydrochloric acid gives a red colour (due to lignin). A mixture of ferric chloride and potassium ferricyanide solutions gives a blue colour (Prussian blue) owing to the reduction of the ferric ferricyanide by the lignin.

Bleaching of jute. As mentioned above, strong solutions of bleaching powder produce chlorinated compounds. A pure white cannot be obtained with jute, but a cream may be produced by the following treatment. Steep the material in warm water, boil it in a solution of soda ash, hydro-extract it, and wash it well. Another method consists of treating the solution for two hours at 70° C. in a $\frac{1}{2}$ per cent. solution of sodium silicate, chemicking it with sodium hypochlorite ($\frac{3}{4}$° Tw.), rinsing or hydro-extracting it, souring it with hydrochloric acid ($\frac{1}{2}$° Tw.), and washing it thoroughly. Jute may be bleached with permanganate, and it is an advantage to carry out such a bleach on jute bleached as above. The bleaching should be followed by a soaping and blueing.

Jute dyeing. Jute is generally dyed unbleached with bright basic dyes.

Uses of jute. The backs of carpets and the fronts of some cheap carpets are made of jute. It is very noticeable how jute carpets become brittle and the colours dull. Poor qualities of jute are used for sacking and for paper manufacture.

Ramie, China grass and rhea. These consist of the bast of *Boehmeria nivea*, a perennial of the nettle type. The plant grows abundantly in China and Japan, and is also cultivated in India and neighbouring countries, in the S. United States and in Jamaica. The fibres are not easily obtained from the stalks by retting, and are generally obtained from the green stalks by special decorticating machinery. One ton of green stalk yields about 150 lbs. of fibre. After separation, the fibre is boiled with water and dried. It is then treated with alkalis to produce a lustre. During this treatment about 20 per cent. of nitrogenous matter is lost.

Microscopic appearance. The individual cells of ramie are extremely long, varying from 6 to 25 cm., and are 0·080 mm. in thickness. The diameter varies considerably, and some cells are narrow with thick walls and distinct lumen, while others are broad with indistinct lumen and many longitudinal striations.

Physical properties. Ramie may be either a tough unbleached yellow fibre suitable for rope making or a fine bleached, pure white, **cottonised ramie** consisting of the long individual cells. In the latter form it may be spun into fine yarns. Ramie is 15 per cent. stronger than the best linen and is less liable to mildew than cotton. It lacks the elasticity of wool and silk, and is less flexible than cotton.

Chemical composition.

	Per cent.
Cellulose	66·2
Pectic and other matters	9·8
Fat and wax	·6
Water extract	10·3
Moisture	10·1
Ash	3·0

Chemical reactions of ramie. Bleached ramie consists of almost pure cellulose and behaves towards reagents as cotton. It gives a blue colour with iodine and sulphuric acid, has a very small affinity for basic dyes and a strong affinity for substantive dyes.

Bleaching of ramie. Ramie is easily bleached by boiling with caustic soda, and then chemicking and souring.

Uses of ramie. Ramie is used for ropes and sail cloth and cottonised ramie for cellular wear, and, on account of its long staple, for adulterating mohair.

Coir or cocoanut fibre. This is obtained from the fibrous shell of the cocoanut. It consists of a very impure lignocellulose, and is used for making mats and cordage owing to its great resistance to mechanical wear. Coir is generally dyed in the raw state, but may be bleached with bleaching powder. Other reagents, such as hydrogen peroxide, permanganate, hydrosulphite, etc., may be used.

Kapok. This is a thistledown obtained from Java. It is very difficult to wet out and is springy, and so finds its chief use in upholstery.

Vegetable wool. This fibre is obtained by fermentation and mechanical treatment of green pine cones. It is mixed with cotton or wool and used for stuffing mattresses and upholstery. Mixed with sheep's wool it is made into hygienic flannels.

Straw and wood fibre. The former contains 55 per cent. and the latter 46 per cent. of cellulose. They are used for plaiting. Straw has a hard glossy exterior containing a large amount of mineral matter, principally silica. Both are generally bleached by boiling out, followed by stoving or treatment with hydrogen peroxide.

Paper has, during recent years, been used for yarns. The paper is cut into thin strips and twisted into yarns. The best yarns are those which are wound round a cotton thread. Cloths made from these yarns may be used for mattings for bedrooms and bathrooms. For coloured paper yarns the material is dyed in the pulp form.

Cosmos fibre is the name given to the manufactured residues of linen, jute, and hemp. These residues are generally mixed with cotton and spun.

Artificial silks. The manufacture of the artificial silks in common use has already been mentioned. It is not easy to distinguish readily one class from another. The microscope gives very little assistance even when the diameters and cross-sections of the fibres are noted. Generally speaking, the fibres are more or less regular in breadth and from oval to circular in form. Acetate silk is the most regular and it has no longitudinal striations. Its cross-section shows less flattening than the other fibres.

Identification of the artificial silks. The most definite test is to put a piece of the silk in strong sulphuric acid.

Nitrocellulose silk remains colourless for half an hour and then becomes faintly yellow. Cuprammonium silks at once turn yellow and, in half an hour, dissolve forming a yellowish red solution. Viscose quickly turns a reddish brown and dissolves to a brown solution. Nitrocellulose silks, although denitrated, always contain sufficient nitro-groups to give a blue solution with a solution of diphenylamine in strong sulphuric acid. Acetate silk is soluble in cold acetic acid and insoluble in ammoniacal copper oxide. It has a low Sp. Gr. (1·25 compared with 1·50 of other silks) and does not swell in water. Acetate silk gives a yellow coloration with iodine and sulphuric acid, whereas the other silks give the blue coloration of cellulose. When acetate silk is burned it gives a disagreeable odour and leaves a black residue.

Another artificial silk is made by forcing a water solution of gelatin through fine holes and drying the thread produced. The gelatin is then rendered insoluble by treatment with formaldehyde. This silk, being of animal substance, can easily be identified by chemical means.

Physical properties. The artificial silks generally possess a greater lustre than natural silks. They are, however, inferior in tensile strength, and when wetted lose much more in strength than natural silk. Many improvements have been made in recent years, and in 1915 a viscose silk was obtained with a dry strength per denier of 1·75 grams and a wet strength of 0·75 grams. The corresponding values for natural silk are 2 to 2·5 grams and 1·7 to 2·2 grams.

Chemical reactions of artificial silks. With the exception of gelatin silk, the artificial silks behave like cotton, and are thus readily distinguishable from natural silk. They are dyed like cotton, but viscose gives a darker shade and acetate silk a much lighter shade. The dyeings should be carried out at low temperatures, and the goods, in the wet condition, carefully handled. Viscose may be dyed at the boil. The dyeing of cops, cheeses, or warps on the beam is unsatisfactory owing to the softening and slackening of the fibres when wetted. For weaving, the yarns should be sized to strengthen them and to prevent their separation into the single filaments.

Bleaching of artificial silks. Artificial silks are not usually bleached, but, if necessary, the bleaching is carried out by hypochlorites, and done rapidly.

QUESTIONS VIII.

1. How would you distinguish between linen, cotton and ramie ?

2. Describe the chemical and physical properties by which linen, jute, and hemp can be distinguished from one another.

3. Describe the bleaching of (*a*) linen, (*b*) hemp, (*c*) Tussah silk.

4. How would you distinguish viscose, acetate silk, nitrocellulose silk, and cuprammonium silk from one another ?

CHAPTER IX

OILS AND SOAPS

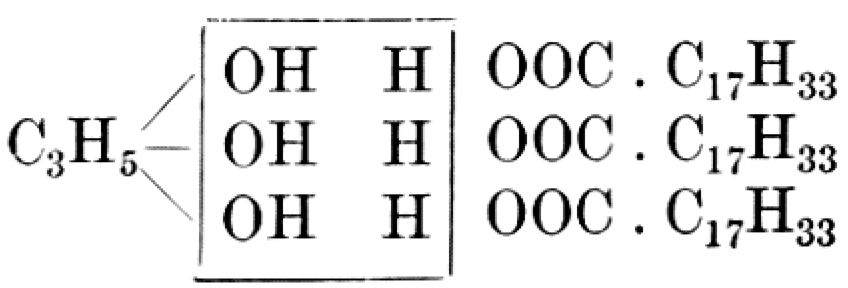
Composition of fats and oils. Vegetable and animal fats and oils may be looked upon as similar to the salts of organic acids of the type R . CO . OH where R is an organic radicle and CO . OH the acid group.

Neutralisation. When sodium hydroxide is added to an acid, say nitric acid, the hydrogen of the acid unites with the hydroxyl group (OH) of the hydroxide to form water, and a salt, in this case, sodium nitrate.

$$\overset{\text{Hydroxide}}{NaHO} \overset{}{+} \overset{\text{Acid}}{HNO_3} \overset{\rightarrow}{=} \overset{\text{Salt}}{NaNO_3} \overset{}{+} \overset{\text{Water}}{H_2O}.$$

The fats and oils may be considered as produced by a similar reaction between glycerol and fatty acids. **Glycerol** has the formula $C_3H_5\,(OH)_3$, and because of the three hydroxyl groups, it is capable of uniting with three molecules of a monobasic acid.

Oleic acid, $C_{17}H_{33}COOH$, is the chief fatty acid present in combination with glycerol in olive oil and may be obtained by the hydrolysis of the oil. It is a monobasic acid, and therefore three molecules will unite with one molecule of glycerol, water being eliminated thus :



$$C_3H_5 \left\langle \begin{array}{|ll|l} \hline OH & H & OOC\,.\,C_{17}H_{33} \\ OH & H & OOC\,.\,C_{17}H_{33} \\ OH & H & OOC\,.\,C_{17}H_{33} \\ \hline \end{array} \right.$$

This gives the formula $C_3H_5 (OOC . C_{17}H_{33})_3$ for **triolein**, the principal constituent in olive oil. Other fats and oils have similar compositions, *e.g.*

tristearin (in tallow), $C_3H_5 (OOC . C_{17}H_{35})_3$,
tripalmitin (in palm oil), $C_3H_5 (OOC . C_{15}H_{31})_3$.

The commercial oleic acid or " oleine " is a by-product in the manufacture of stearic acid. It is an oil, and is largely used for oiling wool and for making soaps to be used in wool scouring. 100 parts by weight of oleine will give a neutral soap with about 48 parts of good potash or 38 parts of soda ash.

Olive oil is obtained from the fruit of olives after the kernels have been removed. There are many qualities depending upon the variety of tree, the ripeness of the fruit, etc., but they may be divided into three grades as follows: (1) oil from the first pressing of the fruit (used for salad oil); (2) oil from the second pressing (used for mordanting); (3) oil from the third pressing (used for soaps).

Tournant oil (**Gallipoli oil**) is rancid olive oil and is used in the old turkey-red dyeing process.

Castor oil is obtained from the seeds of the *Ricinus communis* cultivated in India, the U.S.A., and Java. The first pressing gives " cold drawn " castor oil used for medicinal purposes. Other qualities are obtained by heating the seeds and again pressing.

Turkey red oil or **soluble oil** is prepared from castor oil by treating it overnight with cold sulphuric acid and neutralising the product with soda or ammonia. It consists chiefly of the salts of ricinoleic acid and ricinoleo-sulphuric acid with some hydroxyoleic acid. Turkey red oil D (Badische) is sodium ricinoleate and Turkey red F is sodium ricinoleo-sulphate. The oil is readily soluble in water, and is sold as solutions containing 50 to 60 per cent. of the oil. It should be slightly alkaline or neutral and give a complete emulsion with water. It forms no scum with hard water, and is used considerably in dyeing to give penetration and a soft handle. It is also used as a levelling agent. There are many inferior brands of the oil in which cotton seed, rape seed, olive, cocoanut, etc., oils replace the castor oil.

Monopole oil and **Universal oil** are similar products.

Palmitic acid, $C_{15}H_{31}CO.OH$, is a white solid of melting point 62° C. It occurs in palm oil, olive oil, and most animal fats as tripalmitin.

Stearic acid, $C_{17}H_{35}COOH$, is a white solid melting at 69° C. It is present as tristearin in all solid animal fats, especially in mutton fats.

Ricinoleic acid, $C_{17}H_{33}OH.CO.OH$, melts at 16° C. and occurs as the glyceride (ricinolein) in castor oil.

Soaps. A soap is a metallic salt of a fatty acid.

Expt. 42.—**Preparation of sodium chloride.** In a porcelain dish place a few c.c. of dilute caustic soda and add dilute hydrochloric acid until the solution is just neutral to litmus. The solution tastes like salt water and on evaporation leaves common salt, NaCl.

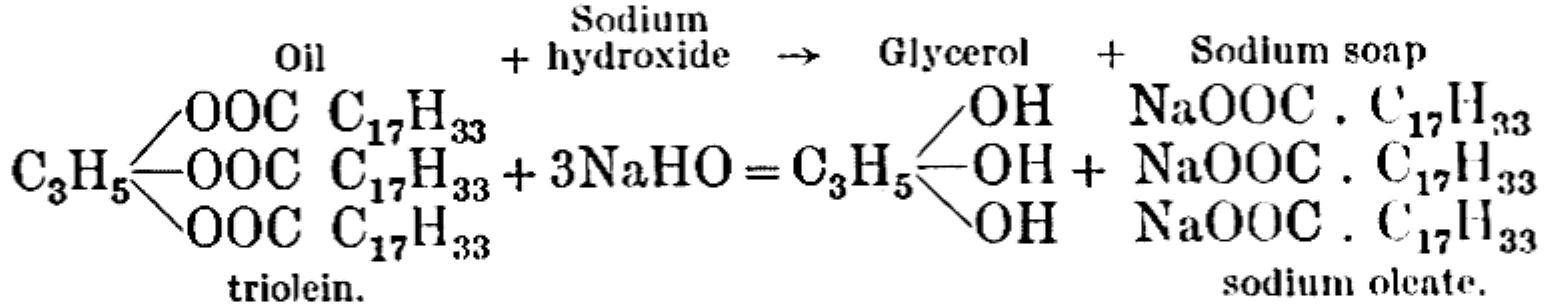
$$\overset{\text{Sodium hydroxide}}{NaOH} + \overset{\text{Hydrochloric acid}}{HCl} \xrightarrow{} = \overset{\text{Sodium chloride}}{NaCl} + \overset{\text{Water}}{H_2O}.$$

Metallic salts of fatty acids may be formed similarly.

Expt. 43.—**Preparation of a soap.** Pour a few c.c. of oleic acid into a porcelain dish, add a few c.c. of sodium hydroxide solution and stir the mixture. A solid soap, which is the sodium salt of oleic acid, is produced.

$$\underset{\text{oleic acid.}}{\overset{\text{Fatty acid}}{C_{17}H_{33}CO\ .\ OH}} + \overset{\text{Sodium hydroxide}}{NaHO} \xrightarrow{} = \underset{\text{sodium oleate (soap).}}{\overset{\text{Sodium soap}}{C_{17}H_{33}COONa}} + \overset{\text{Water}}{H_2O}.$$

Manufacture of soap. Of all the metallic salts of the fatty acids only those of potassium and sodium are soluble in water and therefore available for scouring purposes. Soaps may be made by the direct union of a fatty acid and an alkali (see previous experiment), or by boiling a vegetable or animal fat or oil with an alkali (general method). Taking triolein as the fat, the treatment with alkali (caustic soda) results in the splitting up of the fat (**saponification**) by the addition of three molecules of caustic soda to each molecule of fat with the production of three molecules of soap and one molecule of glycerol (compare formula on p. 118).



$$C_3H_5\left\langle\begin{array}{l} OOC\ C_{17}H_{33} \\ OOC\ C_{17}H_{33} \\ OOC\ C_{17}H_{33} \end{array}\right. + 3NaHO = C_3H_5\left\langle\begin{array}{l} OH \\ OH \\ OH \end{array}\right. + \begin{array}{l} NaOOC\ .\ C_{17}H_{33} \\ NaOOC\ .\ C_{17}H_{33} \\ NaOOC\ .\ C_{17}H_{33} \end{array}$$

From the solution thus obtained the soap may be separated by adding common salt (**salting out**). The lower liquid contains the common salt in solution together with the glycerol. The salt is recovered from this liquid by evaporation, and the viscous liquid left which contains the glycerol is used for explosives or purified for toilet and medicinal purposes. The upper layer consisting of soap is run into a crutching machine, where any additions to the soap are made, and then it is cast into bars. Sodium soaps are hard or **curd soaps.**

Soft soaps. Potassium soaps are made in a similar way to sodium soaps, but they cannot be salted out, and the solution is concentrated by evaporation. The product contains the glycerol and is a soft soap. Great care must be taken in the manufacture because any excess of alkali will remain in the soap. The potassium soaps are more expensive than the sodium soaps, but possess greater detergent properties. Free alkali in soap injures the wool fibre, and a neutral curd soap will therefore be better than an alkaline potash (soft) soap. Alkalinity in potash soaps may be removed by working the soap with an ammonium salt. This reacts with the alkali, forming a neutral salt and liberating ammonia.

Caustic potash + Ammonium salt → Potassium chloride + Ammonia

$$\mathrm{KOH} + \mathrm{NH_4Cl} = \mathrm{KCl} + \mathrm{H_2O} + \mathrm{NH_3}.$$

Household soaps. Many household soaps contain impurities, such as resin, water glass, borax, clay, etc., and should not be used for textile purposes.

Lead soap. When boiled with litharge, PbO, olive oil gives an insoluble lead soap which is used in pharmacy as lead plaster.

Calcium, magnesium, and other metals form insoluble soaps.

Oils used for soaps. Nearly all the common fats, such as tallow, palm oil, cotton seed oil, hemp seed oil, rape seed oil, cocoanut oil, etc., are used for soap making either alone or mixed with others. Soaps of cocoanut oil and palm oil are not readily salted out and may be used with salt water (**marine soaps**). A pure olive oil soap (**Marseilles soap**) is rarely used except for scouring silk. So-called olive oil soap is generally made from cotton seed oil.

When soaps are dissolved in water they are partly decomposed (hydrolysed), forming an acid soap and free alkali. Their action in wool scouring is to form an emulsion with the grease.

Decomposition of soaps. Soaps are decomposed by acids, the fatty acid of the soap being liberated.

Soap + Acid → Salt + Fatty acid

$$\mathrm{NaOOC\,.\,C_{17}H_{33}} + \mathrm{H_2SO_4} = \mathrm{NaHSO_4} + \mathrm{HOOC\,.\,C_{17}H_{33}}.$$

sodium oleate. oleic acid.

This action occurs in the **cracking** (p. 43) of the waste scouring liquors in the seek tanks, the soaps used for scouring, and also the soaps present in the wool sweat, being decomposed and the wool fat thus liberated from its emulsion.

Expt. 44.—**The cracking of soap liquor.** Dissolve a small quantity of soap in water in a test-tube and add a few c.c. of hydrochloric acid. Allow the test-tube to stand and the fatty acid will rise to the surface. When cool the fat will be solid or liquid according to the kind of fat used in the making of the soap.

$$\overset{\text{Soap}}{C_{17}H_{33}COONa} \overset{+\ \text{Acid}\ \rightarrow}{+HCl=} \overset{\text{Fatty acid}}{C_{17}H_{33}COOH} \overset{+\quad\text{Salt}}{+\ NaCl.}$$

Monopole soap is a gelatinous substance similar in composition to Turkey red oil. It has a slightly acid reaction in solution and its lime salts (see next chapter) are precipitated as a fine powder and not produced as a sticky scum. The lime salts are also soluble in excess of the soap, and it can be used advantageously with hard water.

Analysis of soap. The complete analysis of soap will not be given in this book, but a few simple experiments can be carried out to test the quality of the soap.

Expt. 45.—**Estimation of water in soap** Place a few grams of soap shavings, taken from the centre of the soap, in a weighed porcelain dish and weigh again. Heat the dish in a steam oven until the weight is constant. From the loss of weight calculate the percentage of water.

Expt. 46.—**Detection of free alkali in soap.** The amount of free alkali is generally very small. Moisten a freshly cut surface of soap with mercuric chloride solution ; a colouration appears, which is a brownish yellow to a reddish brown according to the amount of free alkali. The taste of a soap is also a rough guide to the alkalinity.

Sapon soap meal is made by working wheat, maize, or other starchy substance into a dough with a definite quantity of caustic soda and water and granulating the product. The meal is soluble in water and, if properly made, has a neutral reaction. It forms no lather, but is a good emulsifier and gives no precipitate with hard waters.

Soap emulsions. Various soap emulsions are on the market under various names. Turkey red oil neutralised with caustic soda (p. 119) is one of these, and others consist of soaps dissolved in, or incorporated with, various solvents, such as the chlorethanes, carbon tetrachloride, etc. To this class belong **Tetrapol**, **Novol**, and **Hexol.**

Wool creams. These have already been mentioned (p. 47), and are generally prepared by mixing water, oil, and ammonia or soap, or by mixing oleine and ammonia and water, but these are not all that could be desired. It is found that the amides (p. 180) and anilides (p. 180) of such acids as oleic and stearic have the property of producing perfect emulsions of other fats, and further improvements have been made by using high molecular weight ketones along with the amides and anilides of oxystearic and oleic-stearic acids. These emulsions are readily removed from the wool by warm water.

QUESTIONS IX.

1. What is the composition of olive oil? What happens when the oil is boiled with a solution of caustic soda?

2. What are soaps? Describe the manufacture of (*a*) a curd soap, (*b*) a soft soap, and state the differences in their compositions.

3. What is turkey red oil, how is it produced, and for what is it used?

4. What are wool creams? State how they may be made, and give their uses.

5. What impurities are found in household soaps, and which of them are to be avoided in a soap used for scouring? Give reasons.

CHAPTER X

WATER

Hardness of water. A hard water is defined as one which does not readily give a lather with soap. The hardness of a water is due to **the presence in solution in the water** of the salts of those metals which form insoluble soaps. When a soap solution is added to, say, a solution of a calcium salt, a calcium soap is precipitated,

$$\underset{\text{Calcium salt}}{CaCl_2} + \underset{\text{Soap}}{2NaOOC\,.\,C_{17}H_{33}} \xrightarrow{} \underset{\text{Calcium soap}}{Ca\,(OOC\,.\,C_{17}H_{33})_2} + \underset{\text{Soluble salt}}{2NaCl},$$

and therefore no lather can be produced in a water containing a calcium salt until the whole of the calcium has been precipitated. Hardness may therefore be defined as the soap destroying power of the water.

Expt. 47.—**Production of a calcium soap.** Make a soap solution by dissolving a small piece of soap in water in a test-tube and add a solution of calcium chloride to it; a white precipitate of a calcium soap is produced.

Expt. 48.—**Testing hardness by soap.** Half fill a pneumatic trough or a large crystallising dish with water from the tap, and make a permanent lather by washing the hands with it. Note the readiness with which the lather is obtained. Repeat the experiment, but first add to the water a quantity of calcium chloride solution. It is now very difficult to obtain a lather and a large amount of scum (calcium soap) is formed.

Lime soap. A hard water wastes soap and produces a **lime soap** (more correctly called a calcium or magnesium soap, according to the metal present) on the materials scoured in it. The lime soap is sticky and is difficult to remove. Its presence may lead to difficulties and faults in the subsequent operations. It is, therefore, essential that a soft water be used for scouring. One pound of calcium carbonate, or its equivalent of calcium or magnesium salts, destroys about 10 lbs. of soap.

Source of hardness. The hardness of a water depends upon the solids dissolved in it, and therefore upon the nature of the soils and rocks through which the water passes. The waters of the earth undergo a natural process of evaporation and the distillate (pure or distilled water) is rain. This rain passing through the air dissolves a small quantity of the carbon dioxide in the air and forms an extremely weak solution of carbonic acid which falls on to the earth.

$$\overset{\text{Water}}{H_2O} \;\overset{+\text{Carbon dioxide}}{+\quad CO_2} \;\overset{\rightarrow\;\text{Carbonic acid}}{= \; H_2CO_3.}$$

Much of the water flows quickly from the surface of the earth into streams and rivers, and has not much opportunity of dissolving substances, but some percolates through the rocks and dissolves substances which are soluble in it. Water collected from limestone and chalk districts is usually very hard, and that from sandstone districts is soft. Limestone is not soluble in pure water, but is soluble in carbonic acid, forming bicarbonates.

$$\overset{\text{Limestone}}{CaCO_3} \overset{+\text{Carbonic acid}}{+ H_2CO_3} \overset{\rightarrow}{=} \overset{\text{Soluble calcium bicarbonate}}{Ca\,(HCO_3)_2 \text{ or } CaCO_3\,.\,H_2CO_3},$$

and thus calcium salts are present in the water. Further, other salts than the bicarbonates are present in water from limestone districts owing to the presence of such substances as calcium sulphate in the limestone.

Temporary hardness. Solutions of bicarbonates are decomposed by boiling and the normal carbonate is formed,

$$\underset{\text{Soluble bicarbonate}}{Ca\,(HCO_3)_2} \xrightarrow{} \; = \; \underset{\text{Insoluble normal carbonate}}{CaCO_3} + H_2O + CO_2,$$

and therefore, when water containing calcium bicarbonate is boiled, the calcium is precipitated as calcium carbonate, and thus the calcium is removed from solution and the water is softened. Hardness which can be removed by boiling is called temporary hardness and is due to the **presence in solution in the water** of bicarbonates of calcium and/or magnesium.

Permanent hardness. When a solution of calcium sulphate, or any calcium salt except the bicarbonate, is boiled, nothing happens, as such salts are more soluble in hot water than in cold, and therefore water containing such substances is not softened by boiling. Hardness which cannot be removed by boiling is known as permanent hardness and is due to the **presence in solution in the water** of salts other than bicarbonates, of calcium, magnesium, and, in small degree, of other metals.

Methods of water softening. It would be too expensive to boil water to soften it even if this did not leave the permanent hardness, and other methods are employed. Lime water when added to a solution of calcium (or magnesium) bicarbonate will precipitate calcium carbonate,

$$\underset{\text{Soluble bicarbonate}}{Ca\,(HCO_3)_2} + \underset{\text{Lime water}}{Ca\,(HO)_2} \xrightarrow{} \; = \underset{\text{Insoluble carbonate}}{2CaCO_3} + 2H_2O,$$

and may be used to remove the temporary hardness. Lime water is itself a hard water because it contains calcium in solution and, if more be added than is just sufficient to precipitate the metal present, the water will be hard again according to the excess of lime water added.

Lime water will not remove permanent hardness, as can be seen from the equation given below :

$$CaSO_4 + Ca\,(HO)_2 = CaSO_4 + Ca\,(HO)_2.$$

If, however, sodium carbonate be added, the calcium will be precipitated as carbonate,

$$\overset{\text{Soluble calcium salt}}{CaSO_4} \overset{+}{+} \overset{\text{Sodium carbonate}\rightarrow}{Na_2CO_3} = \overset{\text{Insoluble calcium carbonate}}{CaCO_3} + Na_2SO_4.$$

Sodium sulphate is left in the water, but as sodium soaps are soluble in water no precipitate can be formed with the soap. Sodium carbonate may therefore be used for removing permanent hardness.

EXPT. 49.—**Precipitation of calcium salts by sodium carbonate.** To a solution of calcium chloride add a solution of sodium carbonate ; the calcium is precipitated as calcium carbonate.

EXPT. 50.—**Softening a hard water.** Repeat Expt. 48, but after adding the calcium chloride add slight excess of sodium carbonate and show that the water is softened.

The housewife uses washing soda, $Na_2CO_3 . 10H_2O$, which acts both as softener and detergent.

From the above it will be seen that waters can be softened by adding a mixture of lime and soda, in calculated quantities, to the water, and this method is largely employed.

EXPT. 51.—**Lime and soda mixture.** To a solution of lime water add a little sodium carbonate solution ; a white precipitate of calcium carbonate is produced and caustic soda left in solution,

$$\overset{\text{Lime}}{Ca\,(HO)_2} \overset{+}{+} \overset{\text{Soda ash}\rightarrow}{Na_2CO_3} = \overset{\text{Calcium carbonate}}{CaCO_3} \overset{+}{+} \overset{\text{Caustic soda}}{2NaHO}.$$

Lime and soda in molecular proportions act like caustic soda, and it seems as though caustic soda alone could be used to soften water. Sodium hydroxide will not soften permanently hard water, because

$$\begin{array}{ccccccc} \text{Calcium salt} & + & \text{caustic soda} & \rightarrow & \text{lime water} & + & \text{sodium salt} \\ CaCl_2 & + & 2NaHO & = & Ca\,(HO)_2 & + & 2NaCl, \end{array}$$

and calcium hydroxide, being moderately soluble in water, will remain in solution, and the water is still hard. Sodium hydroxide will remove temporary hardness,

$$\begin{array}{ccccccccc} \text{Soluble bicarbonate} & + & \text{caustic soda} & \rightarrow & \text{calcium carbonate} & + & \text{soda ash} & & \\ Ca\,(HCO_3)_2 & + & 2NaHO & = & CaCO_3 & + & Na_2CO_3 & + & 2H_2O, \end{array}$$

and at the same time produce sodium carbonate. Now this sodium carbonate will remove a certain amount of the permanent hardness, and therefore under certain conditions, which are seldom met with, sodium hydroxide will free a water of both its temporary and permanent hardness. When the permanent hardness is greater than the temporary hardness, the sodium carbonate produced in the softening of the latter would be insufficient to soften the former completely and some sodium carbonate must be added. On the other hand, if the temporary hardness is greater than the permanent, it will be cheaper to use some lime to soften part of the temporary hardness. The above explanation of the use of sodium hydroxide is of no practical interest because it is in all cases cheaper to use the mixture of lime and soda. It is evident, however, that before the mixture can be used, the hardness of the water must be determined so as to know how much of each reagent to add. With a water of varying hardness this determination must be carried out frequently. The simplest, but not the most accurate, method is by the use of a standard soap solution.

Expt. 52.—**Preparation of a standard soap solution.** Place in a litre flask about 10 grams of fresh sodium oleate or pure Castile soap, add 500 c.c. methylated spirit, and allow the soap to dissolve. Make up the solution to a litre with distilled water and shake well. To standardise the solution prepare the following solution of calcium chloride.

EXPT. 53.—**Preparation of a standard calcium chloride solution.** Weigh out exactly 1 gram of Iceland spar, $CaCO_3$ in a porcelain dish and add a little dilute hydrochloric acid, covering the dish with a clock glass. Allow the substance to dissolve and then evaporate to dryness on the water bath. Redissolve the residue in distilled water and again evaporate to complete the removal of the acid. Now dissolve the residue in distilled water and make up to one litre. Each c.c. of this solution contains calcium chloride equivalent to 0·001 of a gram of calcium carbonate.

EXPT. 54.—Standardisation of the soap solution. Take 20 c.c. of the calcium chloride solution in a stoppered bottle of 250 c.c. capacity and add 50 c.c. distilled water. Run the soap solution in from a burette, 1 c.c. at a time, shaking the bottle vigorously after each addition. When, after an addition, a permanent lather is obtained, read the burette. The titration may be repeated to get a more accurate result. Calculate the volume of water to be added to the soap solution so that 21 c.c. will give a lather with 20 c.c. of the calcium solution. The extra c.c. represents the volume of soap solution required to give a permanent lather with 70 c.c. of distilled water. Add the calculated quantity of water to the soap solution. Again titrate the solutions to see if they are correct. If so, each c.c. of the soap solution will be equal to 0·001 gram of $CaCO_3$. Now 0·001 gram $CaCO_3$ in 70 c.c. is equal to 1 grain per gallon (70,000 grains), and therefore if 70 c.c. of the water be taken, the number of c.c. of soap solution used, minus one, will give the hardness in grains per gallon.

EXPT. 55.—**Estimation of total hardness.** Take 70 c.c. of the water in the stoppered bottle and run in the soap solution until a permanent lather is obtained. Subtract 1 c.c. from the soap solution used, and the remainder gives the number of grains per gallon of total hardness.

Expt. 56.—**Estimation of permanent hardness.** Take about 150 c.c. of water in a flask and counterpoise on a rough balance. Boil the water for 10 minutes to remove the temporary hardness, allow it to cool, and add water until it is of the same weight as before. Filter through a dry filter paper, take 70 c.c. in the bottle, and titrate as before. Subtract the permanent hardness from the total hardness to obtain the temporary hardness.

A more accurate method is given below, but should not be attempted until much practice in volumetric analysis has been obtained.

Determination of hardness (second method). Bicarbonates are decomposed by acids,

$$\underbrace{\underset{40+12+48}{CaCO_3}}_{100} . H_2CO_3 + \underbrace{\underset{2+32+64}{H_2SO_4}}_{98} = CaSO_4 + 2H_2O + 2CO_2,$$

and may therefore be estimated by the use of standard acids (*i.e.* acids of known strengths). The equation tells us that 98 parts by weight of sulphuric acid (H_2SO_4) will neutralise 100 parts of $CaCO_3$ or 1 c.c. of normal (N) H_2SO_4, that is, containing 0·049 grams per c.c. will be equivalent to 0·050 grams $CaCO_3$. Normal H_2SO_4 would be too strong to use for this determination, and a known volume should be diluted to 50 times its volume to give N/50 H_2SO_4. 1 c.c. of this acid will correspond to 0·001 gram $CaCO_3$.

Expt. 57.—**Estimation of temporary hardness.** Place 100 c.c. of the water to be tested in a conical flask, add just sufficient methyl orange to colour it, and run in the N/50 H_2SO_4 till the colour changes. The number of c.c. used will give the number of parts by weight of calcium carbonate in 100,000 parts of water.

The sulphates and chlorides of calcium and magnesium are precipitated by sodium carbonate, and as are also the bicarbonates, but the alkalinity of the solution is not diminished by the decomposition of the bicarbonates,

$$CaCO_3 . H_2CO_3 + Na_2CO_3 = CaCO_3 + 2NaHCO_3,$$

for it requires as much sulphuric acid to neutralise $2NaHCO_3$ as it does for Na_2CO_3,

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2,$$
$$2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2H_2O + 2CO_2.$$

For the determination of permanent hardness a N/50 Na_2CO_3 solution, *i.e.* one containing 10·6 grams/litre =0·00106 grams/c.c. is used.

EXPT. 58.—**Estimation of permanent hardness.** Place 100 c.c. of the water to be tested in a porcelain dish, add a known quantity (excess) of N/50 Na_2CO_3 and evaporate to dryness. The bicarbonate of sodium is converted to carbonate by this process,

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2.$$

Add water to the residue and filter. Rinse the dish and pass the rinsings through the filter, and wash the filter paper. Collect the filtrate and washings in a conical flask; tinge with methyl orange and titrate as before with N/50 H_2SO_4. If there be no permanent hardness, the volume of the H_2SO_4 used will be equal to the volume of Na_2CO_3 added and each c.c. less than this volume will represent the volume of N/50 Na_2CO_3 which has been used in removing the permanent hardness. As before, each c.c. represents 0·001 of a gram of $CaCO_3$ in 100 c.c., or parts of CaCO per 100,000 parts of water, *i.e.* the number of degrees of permanent hardness.

Scales of hardness. Notice that the degrees have been calculated differently in the second method from those in the first method. There are several scales of hardness.

1. Clark's scale: 1° on this scale indicates 1 grain of calcium carbonate (or its equivalent) per gallon.

2. Frankland's scale: 1° represents 1 grain per 100,000 grains.

3. Wanklyn's scale: like Clark's except that 1° is allowed for producing a lather with 70 c.c. of distilled water;

∴ 10° on Clark's scale = 9° on Wanklyn's.

To convert Clark's scale to Frankland's multiply by $\frac{10}{7}$.

Calculation of quantities of reagents to be used in softening water. In whatever form the calcium or magnesium is present it is always calculated as calcium carbonate, so that 24 parts of magnesium or 40 parts of calcium present are counted as 100 parts of $CaCO_3$.

$$\underset{\underbrace{40+12+48}_{100}}{CaCO_3} . H_2CO_3 + \underset{\underbrace{40+2\times17}_{74}}{Ca\,(HO)_2} = 2CaCO_3 + 2H_2O.$$

The amount of lime required is evidently 74 grams for 100 grams $CaCO_3$, or 0·74 of a grain of $Ca\,(HO)_2$ must be added per gallon for each degree of temporary hardness (Clark's scale). Also

$$\underset{\underset{40}{|}}{CaSO_4} + \underset{\underbrace{46+12+48}_{106}}{Na_2CO_3} = Na_2SO_4 + CaCO_3,$$

and therefore 1·06 grains of Na_2CO_3 per gallon are required for every degree of permanent hardness.

The magnesium salts are never completely removed by the lime soda process, and the water is never reduced to zero hardness by this process. Many spring waters have a very high degree of hardness. A water with a hardness of 35° would contain 35 lbs. of $CaCO_3$ per 70,000 lbs., *i.e.* 1 lb. per 200 gallons, and each 200 gallons would destroy 10 lbs. of soap or 1 lb. of soap per 20 gallons.

Water softening plants. In these plants arrangements must be made to add the reagents in the correct quantities to the water and to remove the precipitated carbonate by filtration or by settling. The construction of such plants is simple, and brief descriptions are given below of two types.

Archbutt Deeley Process (Bell Bros. Ltd. Manchester). In this plant a large quantity of water is softened in one of the units and, while being used, another quantity is being softened in another unit. Fig. 35 shows one of the units. The large tank is filled with hard water up to a gauge mark, and at the same time the reagents are weighed out and boiled up in the chemical tank by means of live steam. When the tank is full and the valve has been closed, steam is admitted to the blower *A*, causing a current of water to circulate up through the rose *B*, through the three-way tap *C*, down the vertical pipe, and back into the tank through the perforations in the upper row of the horizontal pipes *D*. The three-way tap connecting with the chemical tank is then opened, and the reagent slowly drawn into the circulating current, being thus

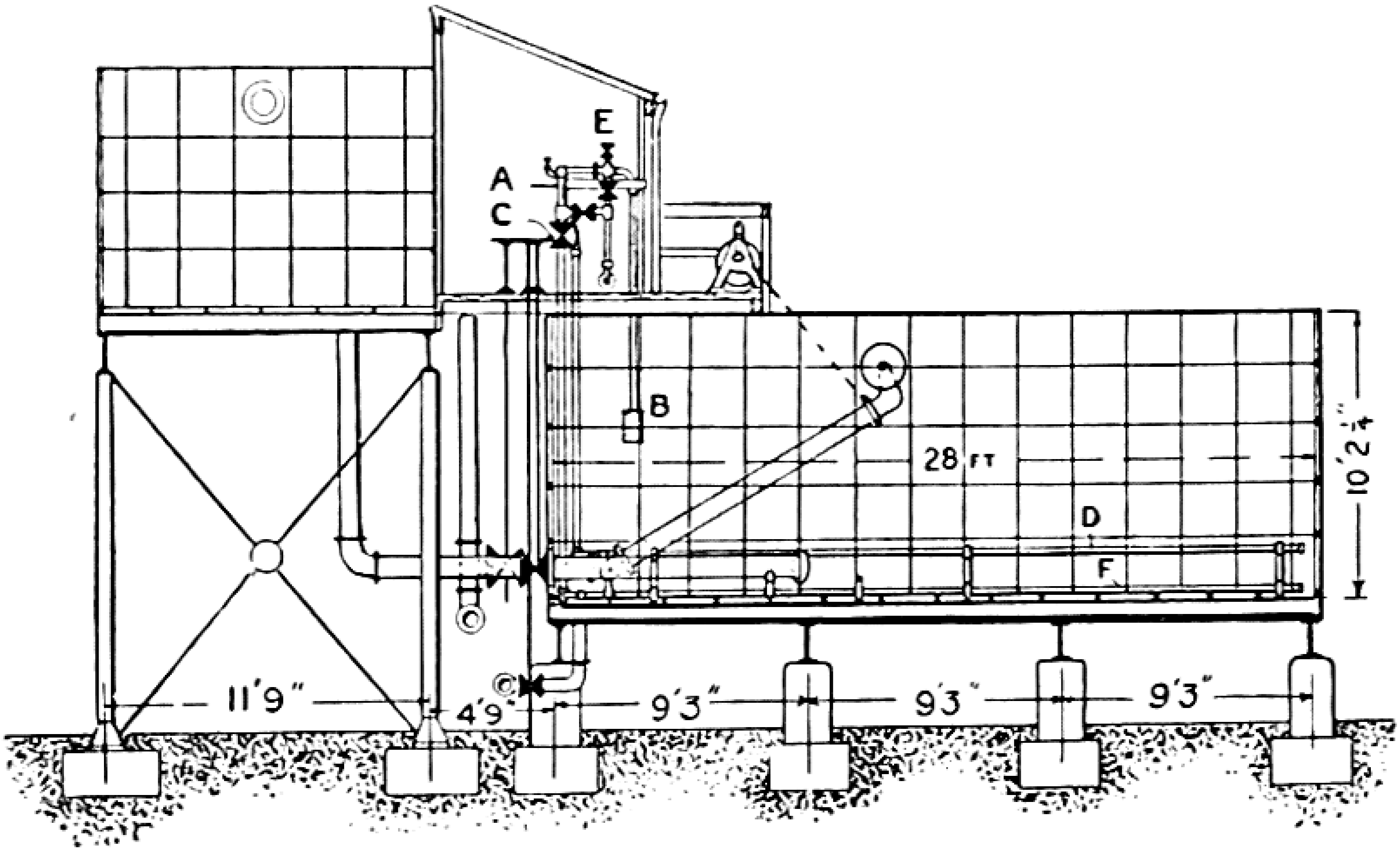


FIG. 35.—Bell's Softener (Archbutt-Deeley type).

diffused throughout the body of the water in the tank. The air tap *E* is next opened to admit air through the pipe to the top of the blower, and the air is blown for a few minutes into the tank through the upper pipes *D*, then by reversing the three-way tap *C* the air is forced through the perforations on the under side of the lower row of pipes *F*, from which it rises in streams of bubbles, stirring up some of the precipitate, or mud, from the previous operations, which lies at the bottom of the tank. After the blower has been in operation for a few minutes, the steam is turned off and, in about one hour, practically the whole of the precipitate settles down to the bottom of the tank. In practice it has been found that, after the period referred to, the water, even down to a depth of 6 ft. from the surface, does not contain on an average more than one grain of suspended matter per gallon.

Bell's Continuous Automatic Water Softener. As its title implies, the softener is automatic, and is similar in general principle to most plants of this type. The principal part of such softeners is the arrangement for regulating the proportion of chemical to water, and the gear used in Bell's plant is shown in Fig. 36. The hard water enters the inlet box, *A*, and flows over two weirs, *WW*. From one of these weirs the water flows directly on to a water wheel, *B*, imparting to it a motion which serves to keep the reagents well stirred in the chemical tank, *C*, and at the same time causes a stream of the mixture to flow through the chemical measurer, *D*. The water from the second weir flows into one of the two float tanks, *E*, raising the float, *F*, and lifting the weight, *G*, which, when it reaches the top of the wheel on which it turns, will fall, tipping the chemical measurer, *D*, and, at the same time, reversing the four-way valve, *V*. The water then flows into the other float tank and the operation is repeated, the float tank previously filled being in the meantime emptied. The reagents from the measurer flow along the channel, *H*, to the water wheel where they are mixed with the hard water and pass to the softener by way of the outlet, *T*. The amount of reagent added to the water is adjusted by the hand wheel, *K*, which

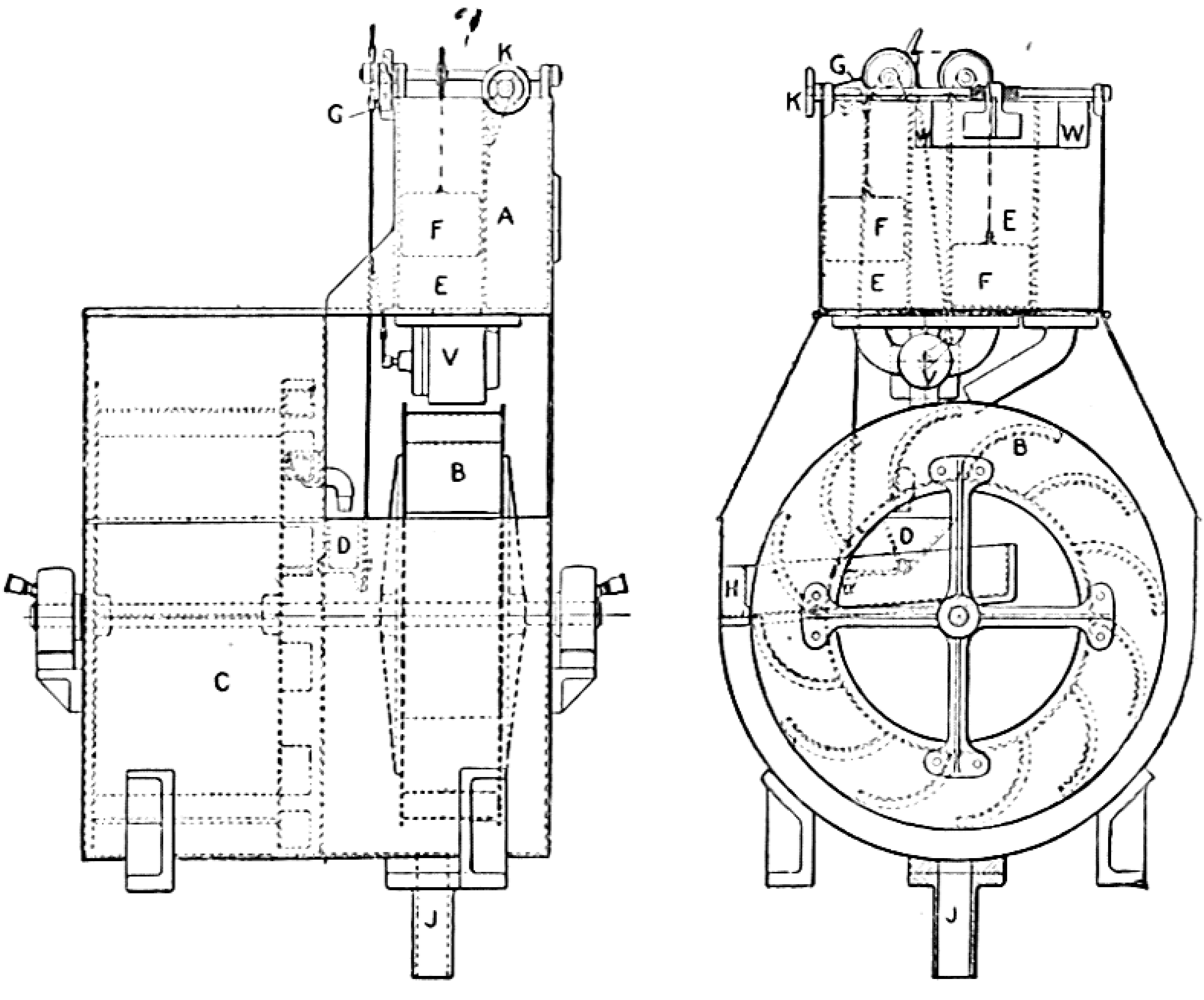


FIG. 36.—Bell's automatic chemical feed gear.

alters the relative widths of the weir. Once adjusted, the proportion of chemical to water remains constant irrespective of the rate of flow of water through the feed gear. The remainder of the plant is fully explained by the illustration, Fig. 37, which shows the feed gear in position.

The softening of a water of constant hardness is simple, but the hardness of river water varies considerably with

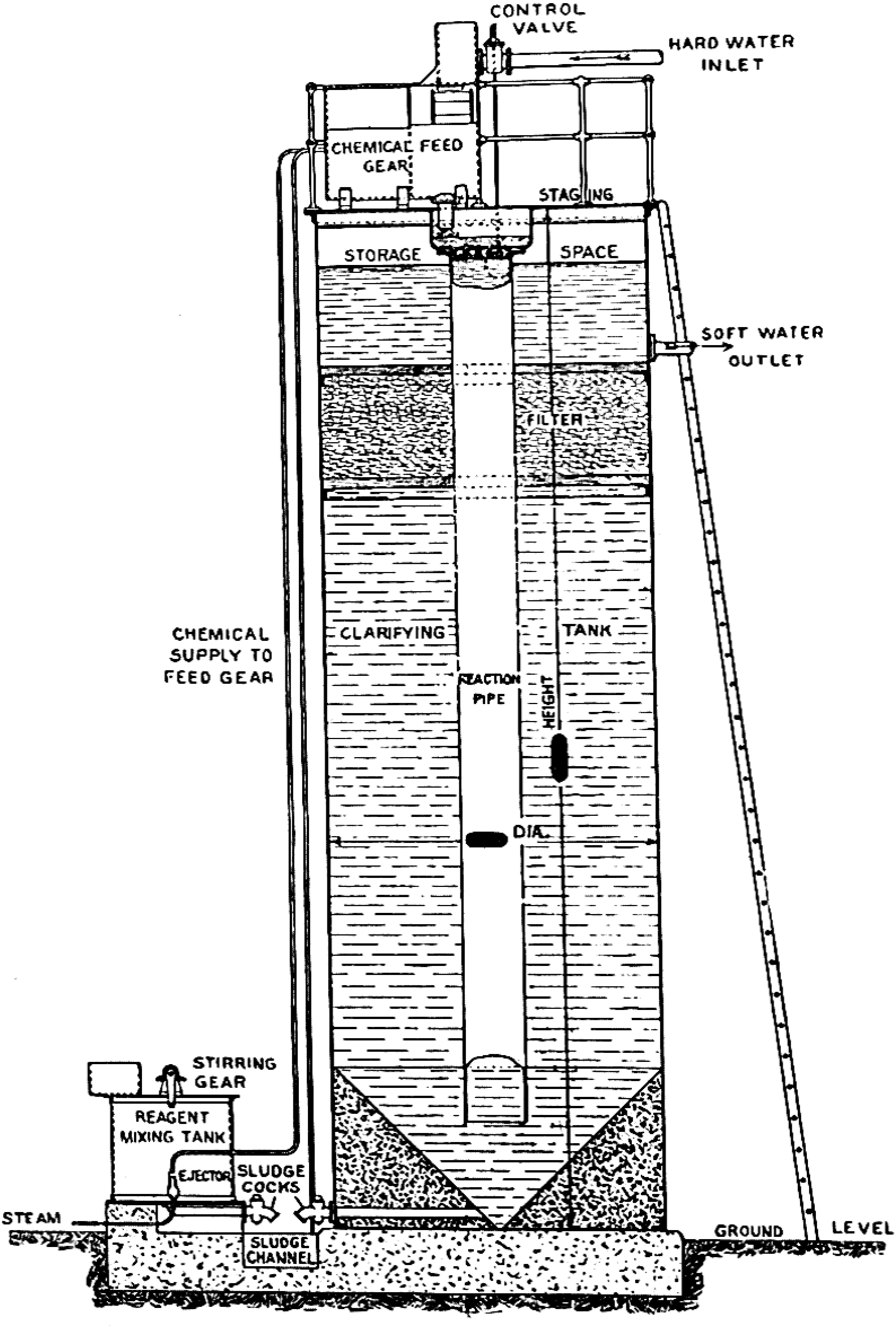
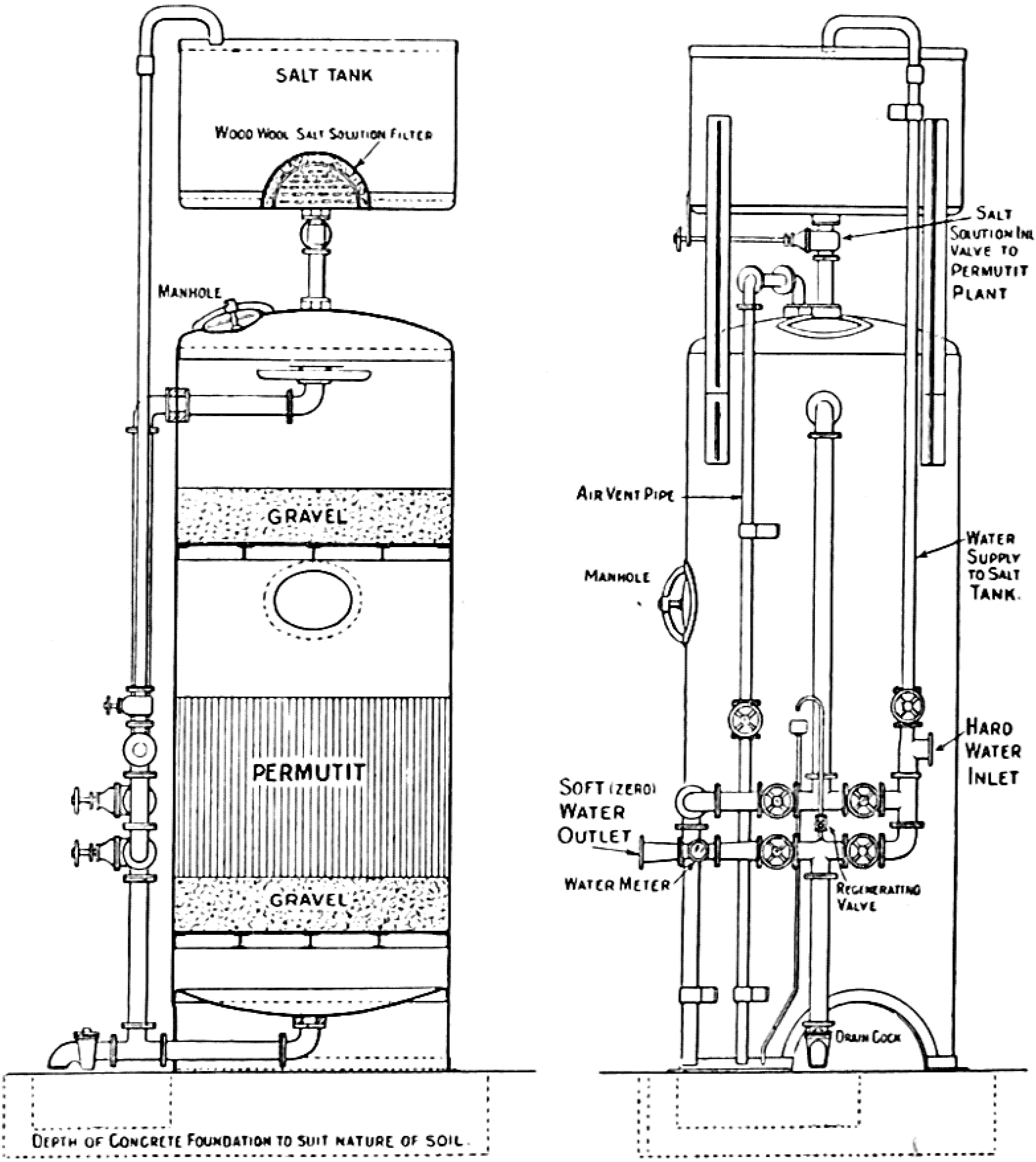


FIG. 37.—Bell's Continuous Type Softener.

the variation in the rainfall and must be frequently tested to determine the correct quantities of the softening agents required.


SALT TANK
WOOD WOOL SALT SOLUTION FILTER
MANHOLE
GRAVEL
PERMUTIT
GRAVEL
DEPTH OF CONCRETE FOUNDATION TO SUIT NATURE OF SOIL.
SALT SOLUTION INLET VALVE TO PERMUTIT PLANT
AIR VENT PIPE
MANHOLE
WATER SUPPLY TO SALT TANK.
HARD WATER INLET
SOFT (ZERO) WATER OUTLET
WATER METER
REGENERATING VALVE
DRAIN COCK

SECTIONAL ELEVATION. FRONT ELEVATION.

FIG. 38.—Permutit plant.

The Permutit softener. The difficulty due to the variation of hardness is obviated by the use of the simple and comparatively new Permutit process. Permutit is a sodium aluminium silicate, $Na_2O . Al_2O_3 . 2SiO_2 . 6H_2O$, and when water is filtered through it, the sodium is partially replaced by the calcium and magnesium in the

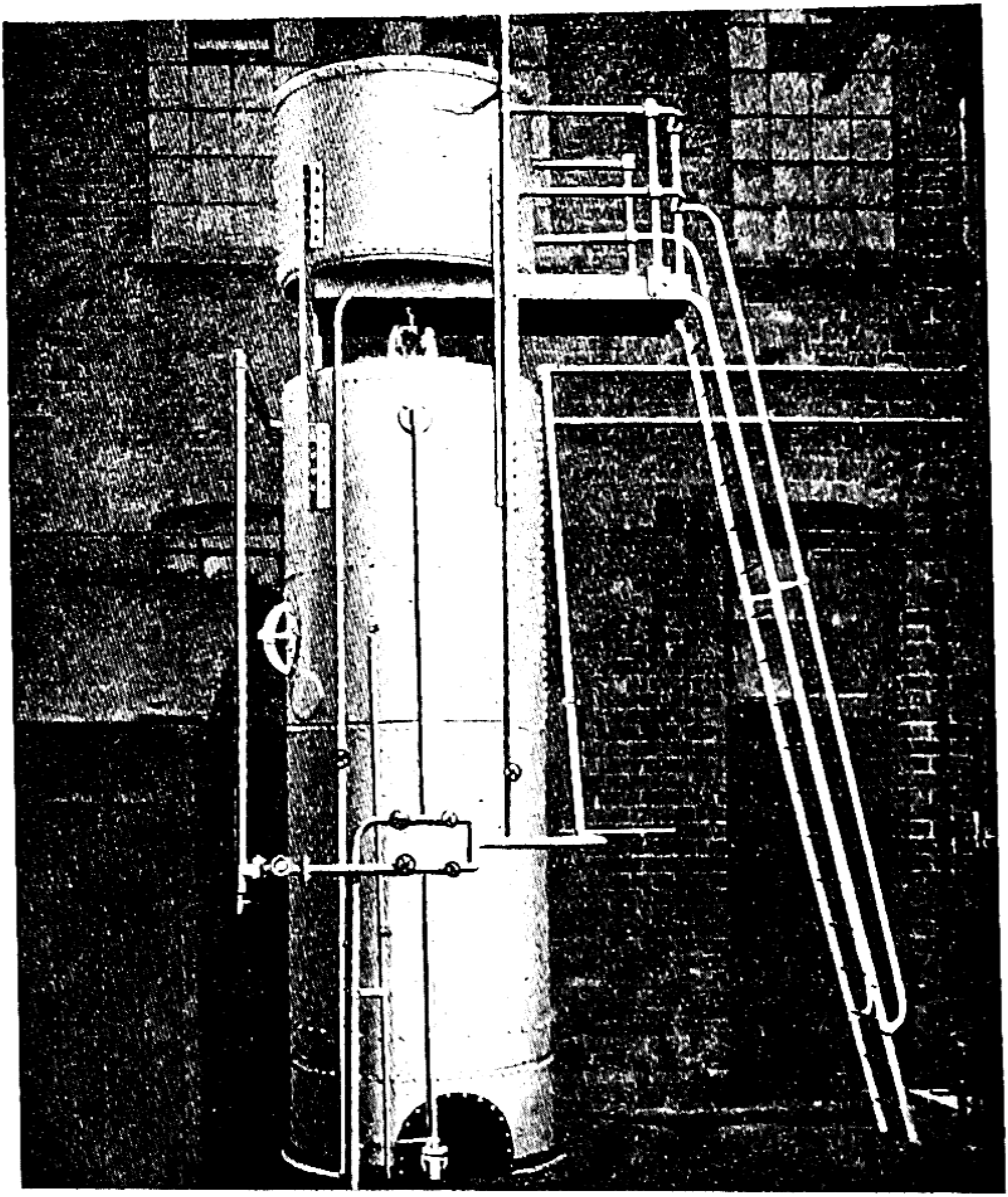


FIG. 39.—Photograph of Permutit plant.

water, and the filtrate, which is free from suspended matter, contains only sodium salts and is of zero hardness. If the permutit is represented by the formula $Na_2\overline{Pm}$, the reaction taking place may be represented thus :

$$\overset{\text{Soluble calcium bicarbonate}}{Ca\,(HCO_3)_2} \overset{+}{+} \overset{\text{permutit}}{Na_2\overline{Pm}} \overset{\rightarrow}{=} \overset{\text{insoluble calcium permutit}}{Ca\overline{Pm}} + 2NaHCO_3,$$

$$\overset{\text{Soluble calcium sulphate}}{CaSO_4} \overset{+}{+} \overset{\text{permutit}}{Na_2\overline{Pm}} \overset{\rightarrow}{=} \overset{\text{insoluble calcium permutit}}{Ca\overline{Pm}} + Na_2SO_4.$$

In time the permutit loses its efficiency owing to the replacement of the sodium, but is easily restored by allowing a solution of common salt to pass through,

$$\overset{\text{Insoluble calcium permutit}}{Ca\overline{Pm}} \overset{+}{+} \overset{\text{common salt}}{2NaCl} \overset{\rightarrow}{=} \overset{\text{soluble calcium chloride}}{CaCl_2} + Na_2\overline{Pm}.$$

The filter is then washed or cleansed by running water through it to remove all traces of salt and is again ready for use.

The above operations may be repeated an unlimited number of times. Iron may be removed from waters by a similar process, using manganese permutit in place of sodium permutit.

The advantages claimed for this process are :

(*a*) Every trace of hardness is removed—no other process will give zero hardness.

(*b*) No deposit is formed, and there is therefore no question of sludge disposal.

(*c*) No regulation is necessary, as variation in quality or quantity of water within the limits of the capacity of the plant makes not the slightest difference.

(*d*) Only one reagent is used, viz. common salt.

(*e*) The process may be worked either under pressure or by gravity.

The process is slightly more expensive than the lime-soda process. Permutit is frequently employed to remove the hardness left after a lime-soda treatment.

Other impurities in water. Iron salts are the worst of all impurities, and, if present, must be removed for all scouring and dyeing purposes. They will of course be estimated as calcium carbonate in determining the hardness of water, because iron soaps are insoluble in water and iron is precipitated by sodium carbonate. Iron salts are generally found in waters from the coal measures. The presence of iron in a spring water is often shown by the yellow colour of the rocks over which the water flows. In small quantities it may be tested for as follows:

EXPT. 59.—**Detection of iron in water.** Evaporate 500 c.c. of the water to dryness in a porcelain dish. A reddish brown residue will indicate the presence of iron which, however, should be confirmed by adding two or three drops of strong hydrochloric acid, then about 1 c.c. of water and a drop of potassium ferrocyanide. A Prussian blue precipitate will be produced if iron is present. As the tap water probably contains no iron, add an extremely minute quantity of a solution of an iron salt, and repeat the experiment to find the delicacy of the test.

Effect of iron in water. Water containing iron will form iron soaps on the fibre during scouring. If afterwards dyed, dull shades will be obtained with the mordant dyes (p. 35), and the dyeings will probably be uneven. Such water will also deposit iron on the fibres during a mordanting process and again give dull shades. Used for bleaching purposes such water would give a yellow tinge, and if the material be afterwards dyed a turkey red, a dull shade would again be obtained.

Moorland waters. These frequently contain peaty matters which affect scouring.

Carbonates in water. Some waters contain much sodium carbonate, and this, alone, is generally advantageous. The bicarbonates of calcium and magnesium may have an effect on mordanting. With bichromates they react, giving chromates which are weaker mordants.

Soluble bicarbonate + bichrome → normal chromates

$$CaCO_3 . H_2CO_3 + K_2Cr_2O_7 = CaCrO_4 + K_2CrO_4 + H_2O + 2CO_2.$$

They also precipitate copper and aluminium salts as hydroxides,

Soluble bicarbonates + aluminium sulphate

$$3CaCO_3 . H_2CO_3 + Al_2 (SO_4)_3$$

→ aluminium hydroxide

$$= 2Al (HO)_3 + 3CaSO_4 + 3H_2O + 6CO_2.$$

If the bicarbonates are insufficient to precipitate the whole of the metal as hydroxide, which, in general, will be the case, a basic salt would be produced, and this would still act as a mordant,

Soluble bicarbonate + aluminium sulphate

$$CaCO_3 . H_2CO_3 + Al_2 (SO_4)_3$$

→ basic aluminium sulphate

$$= Al_2 (HO)_2 (SO_4) + CaSO_4 + HO_2 + 2CO_2.$$

Bicarbonates will also precipitate certain dyes such as alizarine and some basic dyes.

Sulphates in water. Water rich in calcium or magnesium sulphates will slightly mordant wool and produce off shades, but such cases are extremely rare. With this exception, sulphates and chlorides are not injurious in dyeing, and a water is sufficiently rectified for dyeing by adding an acid—acetic acid for preference.

In the dyeing of alizarine, calcium salts are necessary, and, if absent from the water, calcium acetate is added.

QUESTIONS X.

1. What is a hard water ? To what is hardness due, and how would you remove it ?

2. Describe an apparatus for softening water: (*a*) using the lime-soda process, (*b*) by the permutit process.

3. Calculate from the equation (p. 133) the number of grams of soda ash required per 1000 gallons of water for each degree of permanent hardness.

4. How would you determine (*a*) the total hardness, (*b*) the temporary hardness of a water ?

5. How would you test for the presence of iron in water ?

6. Give a list of impurities frequently found in water and say how they affect the scouring, bleaching, dyeing, and mordanting properties of the water in which they are found.

7. What advantages are claimed for the permutit process over the lime-soda process ?

8. What is a lime soap, and what conditions favour the formation of lime soap stains in woollen and worsted goods ?

9. A natural water shows 10° of temporary hardness and 15° permanent hardness on Clark's scale. What quantities of lime and soda would be required to soften 1000 gallons ?

CHAPTER XI

TESTS FOR TEXTILE FIBRES

Identification of the fibres. As mentioned in Chap. I., practice with the microscope provides the quickest and best method of identification of the majority of the fibres, but the student must rely on the experience gained by the examination of known fibres rather than on the diagrams given in text-books.

The following tables of chemical tests are drawn up mainly from the reactions of the fibres given in the previous chapters.

TABLE I.

DISTINCTION BETWEEN ANIMAL AND VEGETABLE FIBRES.

Tests.	Animal fibres.	Vegetable fibres.
Burn the fibres.	Burn slowly. Smell of burning feathers. Large bead of carbon.	Burn quickly. Smell of burning paper. Small grey ash.
Heat the fibres in a dry tube.	Smell of burning feathers. Ammonia evolved (test with red litmus paper).	Smell of burning paper. No ammonia evolved.
	Liquid on the side of the tube is alkaline.	Liquid on the side of the tube is acid.
Boil fibres in a test-tube with a 2 per cent. solution of caustic soda.	Dissolve.	Do not dissolve.
Warm with magenta solution for a few minutes, take out and rinse.	Dyed red.	Not dyed.
Warm in a solution of an acid dye (acid magenta). Rinse.	Dyed.	Not dyed.

TABLE II.

DISTINCTION BETWEEN WOOL AND SILK.

Test.	Wool.	Silk.
Heat in a dry tube, and hold over the end of the tube a filter paper moistened with lead acetate solution (see Expt. 10).	Filter paper turned black due to liberation of sulphuretted hydrogen.	No blackening.
In a porcelain dish place a few c.c. of lead acetate solution, add a little caustic soda (slight excess), boil, place the fibres in for a few seconds (see Expt. 11).	Blackened owing to the formation of lead sulphide.	No blackening.
Boil for one minute in a solution of basic zinc chloride.	Loses 0·5 per cent.	Dissolves.
Place fibre in cold ammoniacal copper oxide (p. 92).	Does not dissolve.	Dissolves.
Place fibre in ammoniacal nickel oxide (p. 146).	Does not dissolve.	Dissolves.
Place in an alkaline copper sulphate solution.	Does not dissolve.	Dissolves.
Boil the fibre with strong hydrochloric acid (p. 73).	Slightly affected.	Dissolves.

Note.—Cotton loses 1·5 to 2 per cent. in the basic zinc chloride, dissolves in ammoniacal copper oxide, loses 1 per cent. in ammoniacal nickel oxide, and is only slightly affected by strong hydrochloric acid.

TABLE III.

DISTINCTION BETWEEN THE VEGETABLE FIBRES.

Test.	Cotton, linen, and ramie.	Hemp.	Jute.
Treat the fibre with iodine and sulphuric acid.	Blue colour.	Green blue.	Yellow.
Place fibre in aniline sulphate.	—	Faint yellow.	Golden yellow.
Warm in phloroglucinol solution.	—	Pale violet red.	Deep red.

Solutions used in the chemical tests :

Magenta (fuchsine) solution : to a saturated solution of magenta in water add caustic soda, drop by drop, till the colour disappears.

Zinc chloride solution : a concentrated solution.

Basic zinc chloride : dissolve 100 grams of zinc chloride in 85 c.c. of water and add 4 grams of zinc oxide. Boil till the zinc oxide dissolves.

Ammoniacal copper oxide : see page 92. A solution may be made by placing copper turnings in a bottle, covering them with strong ammonia solution, and allowing the mixture to stand. If the bottle be stoppered, the copper takes a few weeks to dissolve.

Ammoniacal nickel oxide : to a solution of 5 grams of nickel sulphate in 100 c.c. of water add caustic soda sufficient to precipitate the nickel as hydroxide. Filter, wash, and dissolve the precipitate in 25 c.c. of strong ammonia diluted with an equal volume of water.

Alkaline copper sulphate solution : dissolve 15 grams of copper sulphate in 150 c.c. of water and add 10 grams of glycerol. Add caustic soda solution to this until the precipitate, at first formed, redissolves.

Iodine and sulphuric acid : add slight excess of iodine to 100 c.c. water in which has been dissolved 0·1 gram of potassium iodide. The fibres are first steeped in this and the excess pressed out between filter paper. They are then treated with a mixture of 3 parts concentrated sulphuric acid, 1 part of water, and 3 parts glycerol. This, and many others of the tests, are best carried out under the microscope, the reagents being added to the fibres on the microscope slide.

Aniline sulphate : a concentrated solution of the salt in water made slightly acid with sulphuric acid.

Phloroglucinol solution : dissolve 3 grams of phloroglucinol in 25 c.c. of alcohol and add an equal bulk of strong hydrochloric acid.

Distinction between cotton, ramie, and linen. Cotton and ramie give similar reactions, and are distinguished from linen by the tests given on p. 108. Cotton and ramie are distinguished by the microscope.

TABLE IV.

DISTINCTION BETWEEN NATURAL AND ARTIFICIAL SILKS.

Test.	Mulberry silk.	Tussah silk.	Artificial silks.
Boil fibre in a 10 per cent caustic potash solution.	Dissolves in 10 mins.	Dissolves in 30 mins.	Do not dissolve.
Place fibre in cold strong hydrochloric acid.	Dissolves rapidly.	Does not dissolve in 48 hrs.	Do not dissolve.

Note.—The table does not include gelatin silk (p. 116) among the artificial silks. Gelatin silk being animal matter would dissolve readily in caustic potash.

TABLE V.

DISTINCTION BETWEEN THE VARIOUS ARTIFICIAL SILKS.

Test.	Nitrocellulose silk. Cuprammonium silk. Viscose silk.	Acetate silk.	Gelatin silk.
Burn the fibre.	Smell of burning paper. Grey ash.	Pungent smell. Black residue.	Smell of burning feathers. Black residue.
Heat in a dry tube, and test liquid on side of tube with litmus paper.	Acid.	Acid.	Alkaline.
Heat fibre with iodine and sulphuric acid.	Blue.	Yellow.	Yellow-brown.
Place fibre in strong acetic acid.	—	Dissolves rapidly.	Dissolves rapidly on boiling.

TABLE VI.

DISTINCTION BETWEEN NITROCELLULOSE SILK, CUPRAMMONIUM SILK, AND VISCOSE SILK.

Test.	Nitcocellulose silk.	Cuprammonium silk.	Viscose silk.
Place fibre in strong sulphuric acid in a porcelain dish and add small piece of diphenylamine.	Blue.	Not blue.	Not blue.
Treat fibre with strong sulphuric acid.	Remains colourless for half an hour and then becomes faintly yellow.	At once turns yellow and in half an hour dissolves, forming a yellowish red solution	Quickly turns reddish brown and dissolves, forming a brown solution.

Analysis of mixtures of fibres. The student should remember that the following analyses give results which are liable to an error of at least 1 per cent. of the weight of the substance estimated, and he should in all cases try to account for such error.

EXPT. 60.—**Analysis of a union of cotton and wool.**

Finishing materials or dressing. Weigh exactly about 5 grams of the material. Boil the sample for 10 minutes in a 1 per cent. solution of hydrochloric acid, rinse it, boil it for 20 minutes in a 0·05 per cent. solution of sodium carbonate, wash it well in water, allow it to dry in the air and weigh it again. The loss in weight will give the finishing materials. An error may arise here owing to the treated material not taking up the same amount of moisture as the material before the dressing is removed.

Moisture. Heat the treated material at 100° C. until the weight is constant. The loss of weight will be the weight of the moisture, but from the note above, it will be seen that it may not be the same as the moisture in the original wool.

Cotton. Boil the dried material with a 10 per cent. solution of caustic potash until the wool has dissolved, wash the cotton with water, then with very weak acetic acid to remove the last traces of alkali, and again with water. Dry the residue at 100° C. until it is of constant weight. The residue is cotton, but as cotton is slightly affected by this treatment an allowance of 5 per cent. of the weight of this cotton is added. The student could try the effect of the treatment on dried cotton alone to check this allowance.

Wool. This may be obtained by difference from the above determinations or as follows: steep the treated and dried union in sulphuric acid, Sp. Gr. 1·2, for two hours, wash it with water, boil it well for 15 minutes with water, rinse it again in cold water and dry it at 100 °C. till the weight is constant. The residue is wool, and the cotton may be found by difference.

EXPT. 61.—Repeat the above analysis, but carry out as follows. Weigh three 5-gram pieces and estimate the moisture in one, remove wool from the second and cotton from the third, as in previous experiment. Take the difference as dressing.

EXPT. 62.—**Analysis of union of cotton and wool.** Vary the analysis by removing the cotton with ammoniacal copper oxide treatment for 20 minutes.

EXPT. 63.—**Analysis of union of wool and silk.** Remove the silk with (*a*) strong hydrochloric acid, (*b*) ammoniacal nickel oxide, (*c*) basic zinc chloride.

EXPT. 64.—**Analysis of union of cotton and silk.** Remove silk as in previous experiment.

EXPT. 65.—**Analysis of mixture of cotton, silk, and wool.** Remove the silk by ammoniacal nickel oxide and then the wool from the residue by caustic potash.

Other methods of separation should be drawn up and the results obtained from them compared with those obtained by the above methods. In all cases a slight correction may be made for loss of weight due to treatment for removal of one substance, but such correction is frequently omitted.

Methods of separation of, say (*a*) mulberry silk and Tussah silk, (*b*) wool and artificial silk, etc., should be tried.

QUESTIONS XI.

1. How would you show the presence of (*a*) sulphur in wool, (*b*) nitrogen in silk, (*c*) carbon in cotton ?

2. Give full details of the method you would adopt to analyse a union of cotton and wool, stating where errors are liable to be made. Give the cause of such errors.

3. How would you show the presence of wool in (*a*) a union of wool and cotton, (*b*) a mixture of silk, cotton, and wool ?

4. Draw up a table for the detection of the artificial silks—viscose, nitrocellulose, cuprammonium, acetyl, and gelatin silks.

CHAPTER XII

CHEMICALS USED IN TEXTILE WORK

ACIDS

Sulphuric acid, H_2SO_4, is sold as B.O.V. (brown oil of vitriol) containing 76 to 80 per cent. of H_2SO_4, and D.O.V. (double oil of vitriol), which is the commercial concentrated sulphuric acid, and contains over 95 per cent. H_2SO_4. A table showing the percentages of H_2SO_4 in solutions of the acid of different specific gravities is given on page 176. Sulphuric acid is a strong acid and is cheap. It is a dibasic acid and so forms two series of salts, the sulphates and bisulphates. Sulphuric acid is used in bleaching, dyeing, and mordanting; for cracking waste scouring liquors; for stripping; for carbonising; for discharging indigo; and for the preparation of Turkey red oil.

Fuming sulphuric acid, Nordhausen sulphuric acid, pyrosulphuric acid, oleum, $H_2S_2O_7$, is made by the contact process. The formula $H_2S_2O_7$ represents nearly 90 per cent. of SO_3. The commercial acid oleum is sold containing from 87 to 92 per cent. SO_3 and is used in the manufacture of dyes.

Hydrochloric acid, muriatic acid, is a solution of hydrogen chloride, HCl, in water, the commercial acid containing about 28 per cent. HCl. It is used in cotton bleaching (for souring); in aniline black dyeing; in carbonising rags, etc. It is more expensive than sulphuric acid, and its strength may be found from its Sp. Gr. (p. 177), but more accurately by volumetric analysis.

Nitric acid, HNO_3, is only used to a slight extent in textile work, but is extensively used in the manufacture of dyes and explosives.

Aqua regia is a mixture of strong hydrochloric acid and strong nitric acid (3 : 1). It is used, when diluted, for bleaching silk.

Oxalic acid, $(COOH)_2 . 2H_2O$, is a white crystalline solid chiefly used as an assistant in mordanting. It is also used for the preparation of oxalates of tin, calcium, etc.; as a solvent for colour lakes, and is therefore employed in dyeing single bath mordant dyes such as cochineal. It is sometimes, but rarely, used as a bleaching agent. Along with bichrome (p. 166) and sulphuric acid it increases their power as a stripping agent.

Tartaric acid, $(CHOH)_2 . (COOH)_2$, is a colourless crystalline substance obtained from grapes and is expensive. It is used mainly in silk dyeing for scrooping and brightening (p. 73); also in wool dyeing and calico printing. Its chief salt is "**tartar.**"

Citric acid, $C_6H_8O_7 . H_2O$, obtained from lemons, but is manufactured by the fermentation of glucose. It is a colourless crystalline solid readily soluble in water. It is expensive and rarely used.

Lactic acid, $CH_3CHOH . COOH$, is sold as a syrupy liquid obtained by the fermentation of sour milk. It is used as an assistant in the mordanting of wool with bichrome. The acid potassium salt is called **lactolin** and is also used as an assistant.

Oleic acid (see Oils and Soap, Chap. IX.).

Carbolic acid, phenol, C_6H_5OH, is an antiseptic, and is used as an addition to sizes and finishing materials, but has the disadvantage of being volatile.

Acetic acid, pyroligenous acid, CH_3COOH, is one of the products of distillation of coal tar, and is also formed by the fermentation of alcohol. The pure acid is a colourless solid which melts at 17° C. and boils at 118° C. It is used instead of the much stronger sulphuric acid in the dyeing of certain acid dyes, and for the preparation of acetates. It is expensive.

Formic acid, $HCOOH$, is a colourless pungent-smelling liquid of boiling point 101° C. It is used as an assistant in chrome mordanting and acts as a reducing agent. It is also used in wool dyeing, and may be used with cotton, because it is a volatile acid and will not dry on the cotton and cause tendering.

Salicylic acid, $C_6H_4(OH)COOH$, is a white crystalline solid used as an antiseptic.

TANNIC ACID AND THE TANNINS.

Tannic acid, gallotannic acid, tannin, is generally sold in the form of a yellow powder. It is extracted from gall nuts, and its solution in water should be clear and almost colourless. It is used for mordanting cotton and linen. Other substances may be employed instead of pure tannic acid, the chief being:

Oak galls. The **Aleppo and Levant galls** are the best and contain 50 to 60 per cent. of gallotannic acid. **Japanese and Chinese galls** contain 65 to 75 per cent. of gallotannic acid. Pierced and broken galls contain less tannic acid than the whole ones.

Sumac consists of the leaves sometimes mixed with small stems of a shrub of the Rhus species. Sicilian sumac is the best and contains 15 to 20 per cent. of gallotannic acid. The best varieties are the least highly coloured, the shade being olive green.

Sumac extract is sold at 52° Tw. and is bleached. The best qualities are used for dyeing pale shades.

Myrobalans are the dried fruit of trees growing in the E. Indies and China. They contain from 25 to 45 per cent. of ellagitannic acid together with a brown dye which stains cotton during mordanting and can only be used for blacks or dark shades.

Other tannins, of which **Divi-divi** and **Chestnut extract** are the best, are used, but owing to their dark colours can only be used for blacks. **Cutch** and other natural dyes contain tannin.

The tannins are absorbed by cotton, linen, and silk, and are largely used for mordanting for basic dyes on cotton and linen. The value of a tannin can only be estimated by making comparative dye trials. Roughly, 10 lbs. tannic acid = 14 lbs. Chinese galls = 18 to 20 lbs. best sumac extract = 40 lbs. sumac leaves = 34 lbs. myrobalan.

Tannic acid and the tannins generally are characterised by the following properties: (*a*) have an astringent taste, (*b*) have acidic properties, (*c*) form inks (black, blue black, and green) with iron salts, (*d*) coagulate gelatin and therefore tan leather.

SODIUM COMPOUNDS

Sodium acetate, $CH_3COONa \cdot 3H_2O$, is used to remove free mineral acids from a bath,

$$\underset{\text{Mineral acid}}{HCl} + \underset{\text{sodium acetate}}{CH_3COONa} \rightarrow \underset{\text{acetic acid}}{CH_3COOH} + \underset{\text{sodium salt}}{NaCl}.$$

This is its function in developing baths in cotton dyeing. It is also used in calico printing and to a small extent in wool dyeing.

Borax, sodium diborate, $Na_2B_4O_7 \cdot 10H_2O$, is a very mild alkali, and is used in dyeing wool with alkali blue and as a solvent for casein in calico printing.

Sodium perborate, $NaBO_3$, when placed in water acts as a weakly alkaline solution of hydrogen peroxide. It is used for bleaching purposes under the name **perborin.** It may be incorporated with soaps and washing powders. **Perborin M.** is a mixture of soap, alkali, and perborin. **Persil** is a mixture of soap, soda ash, sodium silicate, and sodium perborate. **Clarax** is a mixture of borax, sodium phosphate, and sodium perborate.

Sodium carbonate, soda, soda ash, Na_2CO_3. The commercial soda ash contains 98 to 99 per cent. Na_2CO_3. It is cheap and is used in wool scouring as a mild alkaline agent, and should therefore be free from caustic soda. It is used in the bleaching of calico (*e.g.* in the lye-boil); for water softening; as an assistant in cotton dyeing with salt dyes. It is frequently present in sulphur dyes.

Washing soda, $Na_2CO_3 . 10H_2O$, and **crystal carbonate,** $Na_2CO_3 . H_3O$, are also used as scouring agents. Washing soda contains only 37 per cent. Na_2CO_3.

Sodium sesquicarbonate, crystal soda, is

$$Na_2CO_3 . 2NaHCO_3 . 2H_2O.$$

Sodium bicarbonate, $NaHCO_3$, is seldom used.

Sodium percarbonate, $Na_2C_2O_6$, is an oxidising agent and may be used as a bleaching agent, but is too expensive. Its solution in water behaves like a solution of sodium carbonate and hydrogen peroxide, but, being alkaline, readily decomposes, liberating oxygen,

$$\begin{array}{lclcl} \text{Sodium percarbonate} \rightarrow & & \text{sodium carbonate} + & & \text{oxygen} \\ Na_2C_2O_6 & = & Na_2CO_3 & + CO_2 & + O. \end{array}$$

With acids it gives carbon dioxide, hydrogen peroxide, and oxygen.

Sodium chloride, common salt, $NaCl$, is used as an assistant in the dyeing of salt dyes and for salting out soaps.

Sodium hydrosulphite. When zinc dust is added to a solution of sulphur dioxide in water (sulphurous acid), the zinc dissolves and no hydrogen is liberated. A zinc salt of hydrosulphurous acid is formed,

$$Zn + 2H_2SO_3 = ZnS_2O_4 + 2H_2O.$$

If a solution of sodium bisulphite be used, a solution is obtained which yields, at first, crystals of $ZnSO_4 . Na_2SO_3$, but, afterwards, white crystals of $Na_2S_2O_4 . 2H_2O$. These latter crystals may also be obtained by salting out. The substance, $Na_2S_2O_4 . 2H_2O$, is unstable when dry, but less so when in solution. Sodium hydrosulphite is used by the vat dyer who often makes his own by adding to the vat sodium bisulphite and zinc dust. The anhydrous salt may be obtained as a light-grey powder by boiling the hydrated salt with alcohol. This is the **Hydrosulphite conc.** sold by various firms and is stable. It is also sold under the name **Hydros** (Brotherton, Leeds). It is a powerful reducing agent, and is largely used for reducing indigo and other vat dyes, and for decolourising azo dyes. It is decomposed when its solution is boiled, and therefore cannot be used for calico printing.

When **formalin** (a 40 per cent. solution of formaldehyde, $HCHO$) is added to a strong solution of hydrosulphite, a very stable substance, **sodium hydrosulphite formaldehyde**, $Na_2S_2O_4 . 2HCHO . 4H_2O$, is obtained, which is really a mixture of $NaHSO_3 . HCHO$, **sodium bisulphite formaldehyde**, and $NaHSO_2 . HCHO$, **sodium sulphoxylate formaldehyde.** Sodium hydrosulphite itself is not a mixture. The hydrosulphite formaldehyde does not decompose below 100° C., and may be used in boiling solutions for stripping and for calico printing. It is sometimes used for bleaching woollens, but more frequently for bleaching cocoanut fibre, feathers, glue, oils, and soaps. It is sold as **Rongalite C.** simple (Badische), **Hyraldite A.** (Cassella), and **Hydrosulphite N.F.** (Meister). The sulphoxylate compound alone is a still stronger reducing agent, and may be separated from the bisulphite compound owing to its different solubility in methyl alcohol. Further reduction of the sodium hydrosulphite formaldehyde compound with zinc and acetic acid gives the pure formaldehyde sulphoxylate which is marketed as **Rongalite C.**, **Hyraldite C.**, **Hydrosulphite N.F. conc.**, and **Formosul** (Brotherton). The substance is caused to react more strongly in the presence of minute quantities of certain dyes (Induline scarlet, etc.) or other substances (as anthraquinone), and so special brands are sold containing such substances. Brands marked *W* are used for wool. **Rongalite C.W.** and **Hydrosulphite N.F.W.** contain zinc oxide, and are used in acetic acid solution for stripping and also for difficult discharges in delaine printing. The *Z* brands are used chiefly for shoddy and are zinc compounds of formaldehyde hydrosulphite. **Decroline** (Badische), **Hydrosulphite A.Z.**, **Zinc Formosul**, and **Hyraldite Z.** are examples. These are also used with acetic acid, being insoluble in water.

Sodium hydroxide, caustic soda, NaHO, is a white, brittle, crystalline solid readily soluble in water. It may be prepared by boiling a solution of soda ash with lime.

$$\underset{\text{Soda ash}}{Na_2CO_3} + \underset{\text{lime}}{Ca\ (HO)_2} = \underset{\rightarrow\text{caustic soda}}{2NaHO} + \underset{\text{calcium carbonate}}{CaCO_3}.$$

It is put on the market in the form of lumps or leaves, or as a solution (72° Tw. contains 33 per cent. NaHO, see p. 179). It is used for bleaching vegetable fibres (*e.g.* in the lye-boil); for mercerising; for neutralising; for printing indigo; for producing basic aluminium and chrome mordants; and for soap manufacture.

Sodium hypochlorite, $NaClO$, is used as a bleaching agent for vegetable fibres. It is sometimes known as "Eau de Javelle."

Sodium nitrite, $NaNO_2$, is largely used in dye manufacture, and in cotton dyeing for producing the change known as diazotisation.

Sodium peroxide, Na_2O_2, is a pale yellow powder. When added to well cooled acidulated water, hydrogen peroxide is formed,

$$Na_2O_2 + H_2SO_4 = Na_2SO_4 + H_2O_2$$

and such a solution when made alkaline is used for bleaching wool, wild silks, straw, etc. Sodium peroxide is liable to set fire to paper, wood, and other organic substances.

Sodium phosphate, disodium hydrogen phosphate, $Na_2HPO_4 . 12H_2O$, is sold as colourless efflorescent crystals whose solution is slightly alkaline. It is used in cotton and silk dyeing, and in the weighting of silk with tin salts.

Sodium silicate, water glass, is sold as a solution of 72°-77° Tw. and has an alkaline reaction. It is used as a mild lye in bleaching; to make solutions of hydrogen peroxide alkaline; in silk weighting; for fireproofing flannelette; as a mordant in cotton dyeing; as an addition or adulterant in soap; and for dressing cotton warps.

Sodium sulphate when crystalline is known as Glauber's salt and has the formula $Na_2SO_4 . 10H_2O$. The anhydrous salt or calcined Glauber's salt is Na_2SO_4. From the formula it can be calculated that one part by weight of the calcined salt is equal to a little over twice its weight of Glauber's salt. Sodium sulphate is used as a levelling agent in dyeing wool with acid dyes ; in cotton dyeing with salt dyes ; in the finishing of cotton goods ; and as a stripping agent for wool.

Sodium bisulphate, nitre cake, $NaHSO_4$, is a by-product in the manufacture of nitric acid. It behaves in solution as a mixture of sulphuric acid and sodium sulphate,

$$\overset{\text{Bisulphate}}{2NaHSO_4} \overset{\rightarrow}{=} \overset{\text{normal sulphate}}{Na_2SO_4} \overset{+}{+} \overset{\text{acid}}{H_2SO_4},$$

and is used to replace equivalent quantities of these substances in wool dyeing. It is known as tartar substitute.

Sodium sulphide, Na_2S, is sold as lumps obtained from the fused compound, but may be obtained as colourless crystals. It is used for reducing and dissolving sulphur dyes.

Sodium sulphite, $Na_2SO_3 . 7H_2O$, is rarely used.

Sodium bisulphite, $NaHSO_3$, is a white solid, but is generally sold as a solution of 52° Tw. It is a reducing agent and used for bleaching wool and silk, and as an anti-chlor.

Sodium thiosulphate, hypo, $Na_2S_2O_3 . 5H_2O$, is used in solution as an anti-chlor.

Sodium tungstate, Na_2WO_4, is used for rendering materials non-inflammable.

POTASSIUM COMPOUNDS

Potassium carbonate, pearl ash, K_2CO_3, is used in the manufacture of soft soap, and is preferred by some to sodium carbonate in wool scouring owing to its greater emulsifying power. It is, however, expensive.

Potassium percarbonate, $K_2C_2O_6$, behaves like sodium percarbonate.

Potassium chlorate, $KClO_3$, is a powerful oxidising agent, and is used in the production of aniline black and some few other colours. It may be replaced by the cheaper sodium chlorate.

Potassium dichromate, bichrome, $K_2Cr_2O_7$ (see chromium compounds).

Potassium ferricyanide, red prussiate of potash, $K_3Fe(CN)_6$, acts as an oxidising agent and is used as a discharge in cotton printing.

Potassium ferrocyanide, yellow prussiate of potash, $K_4Fe(CN)_6 . 3H_2O$, is a yellow crystalline solid used in the production of Prussian blue and in aniline black dyeing.

Potassium hydroxide, KHO, resembles sodium hydroxide, but is much more expensive, and the cheaper sodium hydroxide is used. Potassium hydroxide is used in the manufacture of soft soaps.

Potassium hypochlorite, KClO, has no advantage over the cheaper sodium salt.

Potassium acid lactate, lactolin, $KC_6H_5O_3$, is sold as a thick liquid of 50 per cent. strength as a substitute for tartar in mordanting.

Potassium permanganate, $KMnO_4$, is a powerful oxidising agent and is used as a bleaching agent.

Potassium binoxalate, $KHC_2O_4 . H_2O$, is used as a mild acid, and also as an assistant in mordanting.

Potassium bitartrate, acid potassium tartrate, cream of tartar, tartar, argol. $KHC_4H_4O_6$, is deposited during the fermentation of grape juice. It is largely used as an assistant in mordanting with aluminium, chromium, etc. With bichrome it exerts a reducing action, and also gives a better exhaustion. Many less efficient substitutes are sold (see sodium bisulphate).

AMMONIA AND AMMONIUM COMPOUNDS

Ammonia, NH_3, is a colourless gas extremely soluble in water. Its strongest solution contains about 1000 c.c. of the gas dissolved in 1 c.c. of water. A table of strengths of ammonia is given on page 179. Ammonia is used where a mild alkali is required, *e.g.* in wool scouring; for making peroxide solutions alkaline; and in the ammonia hydrosulphite vat for wool dyeing. It is also used for mordanting, by precipitation, with lead, iron, and other salts. Ammonia is readily displaced from ammonium compounds by other alkalis, and, ammonia being volatile, ammonium compounds may be used for neutralising excess of strong alkalis thus:

Caustic soda + ammonium salt → common salt + ammonia ↗

$$NaHO + NH_4Cl = NaCl + H_2O + NH_3.$$

Ammonium acetate, $NH_4OOC \, . \, CH_3$, gives a weakly alkaline solution which, on boiling in the presence of wool, slowly liberates ammonia, and the bath becomes acid. For this reason it is used to replace sulphuric acid and acetic acid in the dyeing of acid dyes which have a tendency to rush on the wool and dye unevenly. It is also used as a mild stripping agent for acid dyes on wool and silk. Ammonium acetate is made by neutralising acetic acid with ammonia.

Ammonium carbonate, sal volatile. The commercial solid is a mixture of ammonium bicarbonate, NH_4HCO_3, and ammonium carbamate, but gives a solution of the normal carbonate when dissolved in water and ammonia added.

Ammonium bicarbonate + ammonia → ammonium carbonate

$$NH_4HCO_3 + NH_3 = (NH_4)_2CO_3,$$

Ammonium carbamate + water → ammonium carbonate

$$NH_4OCONH_2 + H_2O = (NH_4)_2CO_3.$$

It is used for wool scouring, and has replaced urine for precipitating alumina on cloth.

Ammonium chloride, sal ammoniac, NH_4Cl, is used for fixing alumina on the cotton fibre from a solution of aluminate of soda.

$$\overset{\text{Sodium aluminate}}{Na_3AlO_3} \; + \; \overset{\text{ammonium chloride}}{3NH_4Cl} \; \overset{\rightarrow}{=} \; 3NaCl + \overset{\text{aluminium hydroxide}}{Al\,(HO)_3} + 3NH_3.$$

Ammonium thiocyanate, ammonium sulphocyanide, NH_4CNS, is a colourless deliquescent, crystalline solid very soluble in water. It is added to certain dyeings carried out in copper vessels to prevent the copper altering the shade. 4 oz. to 250 galls. is sufficient.

Ammonium oxalate, $(COONH_4)_2$, is used to a slight extent to correct the hardness of water by precipitating the calcium salts as calcium oxalate.

CALCIUM COMPOUNDS

Calcium acetate, acetate of lime, $Ca\,(OOC\,.\,CH_3)_2$, is a white or greyish solid used in alizarine dyeings to make the water hard. The calcium enters into the composition of the colour. As iron salts give dull shades when used as mordants, the acetate should be free from iron.

Calcium carbonate, chalk, $CaCO_3$, is used to neutralise acids, *e.g.* in the "chalking" baths in Turkey red dyeing, where it also helps in the mordanting. The chalk should be as a fine light powder, and should show no alkalinity with phenol phthalein.

Calcium chloride, $\mathbf{CaCl_2}$, is very deliquescent, and is used in finishing agents for cotton to keep the material soft.

Calcium oxide, quicklime, CaO, is acted upon by water forming slaked lime.

Calcium hydroxide, slaked lime, $Ca\,(HO)_2$, is used for removing temporary hardness of water; for the preparation of bleaching powder; for fixing iron mordants on cotton; and in certain indigo vats as a mild alkali.

Calcium chlor-hypochlorite, bleaching powder, chloride of lime, $CaOCl_2$, is a white powder. It is not wholly dissolved in water. A clear solution of about ½ to 1½° Tw. is used for the bleaching of vegetable fibre; for chlorinating certain wool materials; and as a discharge in calico printing. The powder should contain from 35 to 39 per cent. of available chlorine.

MAGNESIUM COMPOUNDS

Magnesium chloride, $MgCl_2 . 6H_2O$, is deliquescent, and is used in sizes and finishes for cotton.

Magnesium sulphate, Epsom salts, $MgSO_4 . 7H_2O$, is used in the finishing of cotton goods. It is also used in wool bleaching with permanganate of potash to prevent the formation of a strongly alkaline bath.

ALUMINIUM COMPOUNDS

Aluminium acetate, acetate of alumina, red liquor, red mordant, $Al(OOC . CH_3)_3$, is only known in solution, and is usually prepared by adding a solution of lead acetate to one of aluminium sulphate, allowing the mixture to settle, and drawing off the clear liquid for use.

Lead acetate + aluminium sulphate → lead sulphate + aluminium acetate

$$3Pb(OOCCH_3)_2 + Al_2(SO_4)_3 = 3PbSO_4 + 2Al(OOCCH_3)_3$$

100 lbs. of aluminium sulphate require 171 lbs. of lead acetate. If required pure it is best prepared by dissolving aluminium hydroxide in acetic acid.

Aluminium hydroxide + acetic acid → aluminium acetate

$$Al(HO)_3 + 3HOOC . CH_3 = Al(OOC . CH_3)_3 + 3H_2O.$$

A **sulphacetate** may be made by using less lead acetate in the first method of preparation. These acetates, and also a **basic acetate**, are used in mordanting cotton. Aluminium acetate is used for waterproofing.

Aluminium chloride, $AlCl_3 . 6H_2O$, is used in carbonising, especially for woollen piece goods dyed with colours sensitive to acids.

Aluminium hydroxide, $Al(HO)_3$, may be prepared as a white powder by adding an alkali to a solution of an aluminium salt.

$$Al_3(SO_4)_3 + 6NaHO = 2Al(HO)_3 + 3Na_2SO_4.$$

It is a base, but may exhibit feebly acidic properties towards strong alkalis, and, though insoluble in ammonia, dissolves in caustic soda forming sodium aluminate.

Aluminate of soda, sodium aluminate, alkaline pink mordant. The commercial salt has the formula $Al(HO)_2ONa$, and is used as a mordant for alizarine red on cotton. The goods, after impregnation, are dried and passed through a solution of ammonium chloride which precipitates alumina on the fibres.

$$Al(HO)_2ONa + NH_4Cl = Al(HO)_3 + NaCl + \overset{\uparrow}{NH_3}.$$

Aluminium silicate, Kaolin, China clay, is used in very large quantities for weighting, principally for cotton.

Fuller's earth is an impure aluminium silicate, the colour varying according to the impurities. On treatment with water it falls to powder. It is used as a scouring agent, chiefly for pieces and yarns.

Aluminium sulphate, cake alum, patent alum, conc. alum, $Al_2(SO_4)_3 . 18H_2O$, is used for mordanting wool and should be free from iron.

Alum, potash alum, has the formula $K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$. **Soda alum,** $Na_2SO_4 . Al_2(SO_4)_3 . 24H_2O$, may be used to replace potash alum and is cheaper. **Ammonia alum**, $(NH_4)_2SO_4 . Al_2(SO_4)_3 . 24H_2O$, is also used.

Basic aluminium sulphates are formed by the addition of an alkali to aluminium sulphate or alum.

$$\overset{\text{Aluminium sulphate}}{Al_2(SO_4)_3} + \overset{\text{sodium carbonate}}{Na_2CO_3} + 2H_2O$$

$$\overset{\rightarrow \text{ basic aluminium sulphate}}{= Al_2(SO_4)_2(HO)_2} + Na_2SO_4 + H_2O + CO_2.$$

$Al_2SO_4(HO)_4$ and others are known. These basic salts are soluble in water, and are much quicker in their mordanting action than the normal salt.

CHROMIUM COMPOUNDS

Chromium compounds are very important in mordanting. Chromium forms two common oxides, viz. chromium sesquioxide, Cr_2O_3, a green insoluble basic oxide, and chromium trioxide or chromic oxide, CrO_3, a red deliquescent crystalline acidic oxide. The former corresponds to the chromium salts such as chromium sulphate, $Cr_2(SO_4)_3$, and the latter to the chromates and dichromates. Between these two oxides there are others, as for example Cr_5O_{16}, which is a yellow substance less soluble than CrO_3, and which is **chromium chromate**, $Cr_2O_3 . (CrO_3)_3$. Basic chromium chromates are known.

Wool boiled with chromic acid or potassium dichromate in presence of sulphuric acid is yellow in colour, and probably holds a chromium chromate or basic chromium chromate. This yellow mordant is still an oxidising agent and is not suitable for certain dyes susceptible to oxidation, hence the use of assistants which reduce the yellow compound to green chromium compounds.

Chrome alum, $K_2SO_4 . Cr_2(SO_4)_3 . 24H_2O$, is never used directly because it is too stable. It is sometimes used for after-treating salt dyes.

Chromium acetate is analogous to aluminium acetate, and is prepared similarly and used in the same manner in calico printing.

Chromium chloride, $CrCl_3$, is not used, but the basic chloride, $CrCl(HO)_2$, is used for mordanting silk.

Chromium fluoride, fluo-chrome, $CrF_2(HO)$, is obtained by dissolving **chromium hydroxide**, $Cr(HO)_3$, in hydrofluoric acid. It is a green powder soluble in water, and is used for after-chroming and also for after-treating various salt dyes to increase their fastness to light.

Chromium bisulphite is obtained by dissolving chromium hydroxide in sulphurous acid or from chrome alum and sodium bisulphite. It is an indefinite compound, the formula suggested being $Cr(HSO_3)_3$. It is applied to cotton by padding, and when steamed or dried gives off sulphur dioxide and leaves chromium hydroxide.

Potassium chromate, K_2CrO_4, is a bright yellow crystalline substance and is used in **metachrome mordant**, which is a molecular mixture of the chromate and ammonium chloride. A metachrome mordant may be added to the dye bath at the same time as the dye. The material is dyed and chromed simultaneously owing to the gradual decomposition of the mordant.

Potassium dichromate, bichromate of potash, bichrome, chrome, $K_2Cr_2O_7$, is an orange red crystalline solid soluble in water. It is an oxidising agent, and is largely used as a mordanting agent and as a stripping agent with sulphuric acid.

Sodium dichromate, $Na_2Cr_2O_7 . H_2O$, is the same colour as potassium dichromate and is deliquescent. It is cheaper, more readily soluble in water, and is supplanting potassium dichromate. From the formula it will be seen that potassium bichromate may be replaced by an equal weight of the sodium salt.

Chromium ammonium oxalate or **chromosol** is used for mordanting.

IRON COMPOUNDS

Ferrous sulphate, copperas, green vitriol, $FeSO_4 . 7H_2O$, is a green crystalline solid easily soluble in water. It is used as a mordant for wool; for fixing tannic acid on cotton; and as a reducing agent in the "vitriol" indigo vat.

Acetate of iron, pyrolignite of iron, black liquor, $Fe(OOC . CH_3)_2$, is prepared by dissolving iron in crude acetic acid, and is usually sold as a dark coloured solution of 72° Tw. It is used for mordanting silk and cotton, being applied in the same way as aluminium acetate.

Nitrate of iron is prepared by the oxidation of ferrous sulphate with nitric acid, and consists mainly of ferric sulphate, $Fe_2(SO_4)_3$, and basic sulphate, $Fe_2(SO_4)_2(HO_2$, and also contains $Fe_2(SO_4)_2(NO_3)_2$. It is used in large quantities in silk dyeing, and is usually marketed as a solution of 91° Tw.

MANGANESE COMPOUNDS

Potassium permanganate is the only manganese compound used and has already been mentioned (p. 160).

ZINC COMPOUNDS

Zinc dust is used in indigo vats with sodium bisulphite to produce hydrosulphite.

Zinc oxide, ZnO, and **zinc sulphate**, $ZnSO_4 . 7H_2O$, are found of very little use.

Zinc chloride, $ZnCl_2$, is a white deliquescent solid, and is used in considerable quantities in the sizing and finishing of cotton. It keeps the material soft and is an antiseptic.

COPPER COMPOUNDS

Copper sulphate, blue vitriol, bluestone, $CuSO_4 . 5H_2O$, is employed as an oxygen carrier in aniline black dyeing; for after-treating salt dyes; and in single bath logwood dyeings.

Ammoniacal copper oxide (see page 92).

LEAD COMPOUNDS

Lead acetate, sugar of lead, $Pb(OOC . CH_3)_2$, is used in the dyeing of chrome yellow (a mineral dye), and for the preparation of acetates and sulphacetates of aluminium and chromium.

TIN COMPOUNDS

Acetate of tin, like chromium acetate, is used in calico printing.

Stannous chloride, tin crystals, $SnCl_2 . 2H_2O$, is hygroscopic and dissolves in water forming a cloudy solution. It is used in dyeing Turkey red and cochineal.

Stannic chloride, $SnCl_4$, is a colourless liquid, but is put on the market as the hydrate $SnCl_4 . 3H_2O$, which is a white deliquescent solid known as butter of tin. It is used in cotton dyeing as a mordant, but its chief use is in silk weighting.

Pink salt has almost gone out of use. It is a double salt of stannic and ammonium chlorides, and is used for the same purposes as stannic chloride.

Sodium stannate, stannate of soda, preparing salt, $Na_2SnO_3 . 3H_2O$, is a colourless efflorescent solid used as a mordant in cotton dyeing; for silk weighting; and for making cotton goods non-inflammable.

ANTIMONY COMPOUNDS

Potassium antimony tartrate, tartar emetic,
$K(SbO)C_4H_4O_6 . \frac{1}{2}H_2O$
(43 per cent. Sb_4O_6) is extensively used in a standing bath for fixing tannic acid on cotton. The bath becomes acid with use and must be corrected, sodium carbonate, or even chalk, being used. Owing to the difficulty of dissolving the substance, and also because it is expensive and does not exhaust, other antimony compounds have been put on the market to replace it (see below).

Antimony salt, $SbF_3 . (NH_4)_2SO_4$, (47 per cent. Sb_4O_6) is readily soluble in water.

Patent salt, $SbF_3 . NH_4F$, (66 per cent. Sb_4O_6) is a double fluoride of antimony and ammonium. The sodium salt is also in use.

Antimonin is one of the several lactates of antimony on the market, and is a double lactate of antimony and calcium. It is very readily soluble in water and mordants completely. 1 part of antimonin = 1 part of tartar emetic though it only contains 15 per cent. Sb_4O_6.

Antimony oxalate, antimony potassium oxalate, $K_3Sb(OOC)_3$, contains 25 per cent. Sb_4O_6, and is more readily soluble in water than tartar emetic. It is equal to the latter in mordanting power.

TITANIUM COMPOUNDS

The **titanous salts,** $TiCl_3$, and $Ti_2(SO_4)_3$, are sold as solutions, violet in colour, containing 20 per cent. of the salt together with free acid. They are powerful reducing agents, and may be used for stripping shoddy and for discharging. They are not commercially successful. Titanous chloride is used for estimating the strength of indigo by titration.

Titanic chloride, $TiCl_4$, is found of some use for fixing tannic acid on cotton, but the compounds produced are yellow and therefore not suitable for dyeing light shades.

VANADIUM COMPOUNDS

Ammonium vanadate, NH_4VO_3, is the only compound used in dyeing, its hydrochloric acid solution being employed in aniline black dyeing, a mere trace being sufficient to promote oxidation.

TUNGSTEN COMPOUNDS

Sodium tungstate, $Na_2WO_42H_2O$, has already been mentioned (see sodium compounds).

OTHER COMPOUNDS

Hydrogen peroxide (see p. 59).

Formalin is a 40 per cent. solution of **formaldehyde,** HCHO, (a gas) in water. It is used for after-treatment of certain salt dyes. It renders gelatine insoluble, and is therefore sometimes used in finishing, and in leather tanning.

Carbon disulphide (CS_2), **benzene** or **benzol** (C_6H_6), **carbon tetrachloride** (CCl_4), **petrol**, **methylated spirit** or **impure ethyl alcohol** (C_2H_5OH), **wood spirit** or **methyl alcohol** (CH_3OH), and the **chlor derivatives of ethane**, etc., are used as solvents in dry cleaning.

Quillaya bark, soap bark, contains 8 per cent. of a **glucoside** called **saponin,** which dissolves in water giving a frothy solution which acts like soap. It is not alkaline, and may be used in acid solution. It is used for cleaning delicate fabrics and for finishing high quality indigo dyed pieces, but is very expensive.

Soap nuts and **soap root** or **soap wort**, contain a similar body and have a similar action.

Starch is generally prepared from potatoes and wheat, but may be obtained from rice, barley., maize, etc. By the appearance of the grains under the microscope, the source of the starch and its purity may be determined. Starch may hold up to 35 per cent. of water, and the estimation of this moisture is important. It is used in calico printing and very largely as a finishing agent.

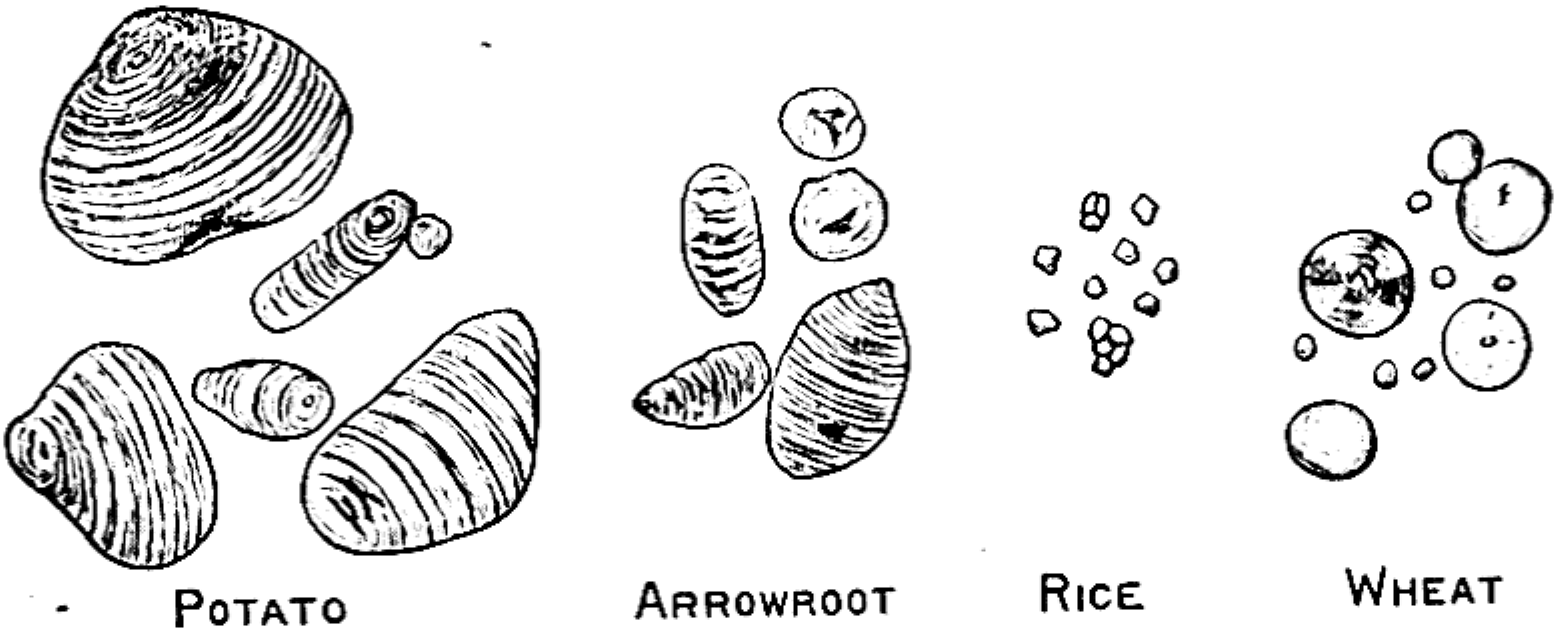


FIG. 40.—Relative sizes and appearances of starch grains.

Soluble starch, or vegetable size, is prepared by heating starch with steam under pressure. It is a clear gummy mass soluble in water, and has lost to a great extent the thickening properties of starch. **Apparatin** is obtained by boiling starch with caustic soda and neutralising the product with sulphuric acid. It is a gummy mass soluble in water. Both soluble starch and apparatin are used as sizing and finishing agents.

Dextrin, British gum, artificial gum, is produced by heating starch. It may also be produced by the limited action of dilute acids or of diastase on starch. It is soluble in water, and should give an almost colourless neutral solution. Dextrin is used in printing and finishing, and gives a blue colour with iodine.

Gum Arabic, Gum Senegal, Gum Tragacanth, are natural gums used in printing and finishing. Glue (hide, bone, fish) is used in finishing.

Bees' wax and **Carnauba wax** are principally miricyl palmitate, *i.e.* compounds of miricyl alcohol and palmitic acid. **Spermaceti wax** is cetyl palmitate. **Waxes** and **resins** are used in waterproofing.

Boiled-off liquor or **Bast Soap.** This is a solution of silk gum, and is slightly alkaline (p. 72). It is used in the dyeing of silk in quantities varying from $\frac{1}{20}$ to $\frac{1}{10}$ of the volume of the dye liquor. When not available, it may be substituted by a solution of best olive oil soap **(Marseilles soap)** together with gelatin or glue.

CONVERSION OF WEIGHTS AND MEASURES.

1 metre = 10 decimetres = 100 centimetres = 1000 millimetres = 39·37 inches

Metres	to yards ;	multiply by	1·094.
,,	,, inches ;	,, ,,	39·37.
Yards	,, metres ;	,, ,,	0·9144.
Centimetres	,, inches ;	,, ,,	·3937
Inches	,, centimetres ;	,, ,,	2·54.

1 litre = 1 cubic decimetre = 1000 cubic centimetres = 0·2209 gallons = 1·76 pints.

Litres	to gallons ;	multiply by	0·2209.
Gallons	,, litres ;	,, ,,	4·5436.

1 kilogram = 1000 grams = 2·205 lbs.

Kilograms	to pounds ;	multiply by	2·205.
Pounds	,, kilograms ;	,, ,,	0·4536.

1 gallon of water at 62° F. weighs 10 lbs.
1 lb. = 453·6 grams = 7000 grains.
1 oz. = 28·35 grams.

Atmospheric pressure = 1033·3 grams per sq. cm. = 14·7 lbs./sq. in.

CONVERSION OF THERMOMETRIC SCALES.

° Centigrade to ° Fahrenheit ; multiply by 9, divide by 5, add 32.

Thus : $15^\circ \text{ C.} = \frac{15 \times 9}{5} + 32 = 61^\circ \text{ F.}$

° Fahrenheit to ° Centigrade ; subtract 32, multiply by 5, divide by 9.

Thus : $120^\circ \text{ F.} = \frac{(120 - 32) \times 5}{9} = 48\frac{8}{9}^\circ \text{ C.}$

CONVERSION OF HYDROMETRIC SCALES.

° Twaddell to specific gravity ; multiply by 5, divide by 1000, add 1.

Thus : $168^\circ \text{ Tw.} = \frac{168 \times 5}{1000} + 1 = 1{\cdot}84 \text{ Sp. Gr.}$

Specific gravity to ° Twaddell ; subtract 1, multiply by 1000, divide by 5.

Thus : $1{\cdot}42 \text{ Sp. Gr.} = \frac{(1{\cdot}42 - 1)\,1000}{5} = 84^\circ \text{ Tw.}$

Specific gravity to ° Beaumé, and *vice versa*.

For liquids denser than water :

$$\text{Sp. Gr.} = \frac{144}{144 - {}^\circ\text{ Bé.}}, \quad {}^\circ\text{ Bé.} = 144 - \frac{144}{\text{Sp. Gr.}}$$

For liquids less dense than water :

$$\text{Sp. Cr.} = \frac{144}{134 + {}^\circ\text{ Bé.}}, \quad {}^\circ\text{ Bé.} = \frac{144}{\text{Sp. Gr.}} - 134.$$

TABLE OF ATOMIC WEIGHTS.

Element.	Symbol.	Atomic Weight (1920).	Element.	Symbol.	Atomic weight (1920).
Aluminium	Al	27·1	Molybdenum	Mo	96·0
Antimony	Sb	120·2	Neodymium	Nd	144·3
Argon	A	39·9	Neon	Ne	20·2
Arsenic	As	74·96	Nickel	Ni	58·68
Barium	Ba	137·37	Niton	Nt	222·4
Bismuth	Bi	208·0	Nitrogen	N	14·008
Boron	B	10·9	Osmium	Os	190·9
Bromine	Br	79·92	Oxygen	O ✓	16·00
Cadmium	Cd	112·40	Palladium	Pd	106·7
Caesium	Cs	132·81	Phosphorus	P	31·04
Calcium	Ca	40·07	Platinum	Pt	195·2
Carbon	C	12·00	Potassium	K ✓	39·10
Cerium	Ce	140·25	Praseodymium	Pr	140·9
Chlorine	Cl ✓	35·46	Radium	Ra	226·0
Chromium	Cr	52·0	Rhodium	Rh	102·9
Cobalt	Co	58·97	Rubidium	Rb	85·45
Columbium	Cb	93·1	Ruthenium	Ru	101·7
Copper	Cu	63·57	Samarium	Sa	150·4
Dysprosium	Dy	162·5	Scandium	Sc	44·1
Erbium	Er	167·7	Selenium	Se	79·2
Europium	Eu	152·0	Silicon	Si	28·3
Fluorine	F	19·0	Silver	Ag	107·88
Gadolinium	Gd	157·3	Sodium	Na ✓	23·00
Gallium	Ga	70·1	Strontium	Sr	87·63
Germanium	Ge	72·5	Sulphur	S	32·06
Glucinum	Gl	9·1	Tantalum	Ta	181·5
Gold	Au	197·2	Tellurium	Te	127·5
Helium	He	4·00	Terbium	Tb	159·2
Holmium	Ho	163·5	Thallium	Tl	204·0
Hydrogen	H ✓	1·008	Thorium	Th	232·15
Indium	In	114·8	Thulium	Tm	168·5
Iodine	I	126·92	Tin	Sn	118·7
Iridium	Ir	193·1	Titanium	Ti	48·1
Iron	Fe	55·84	Tungsten	W	184·0
Krypton	Kr	82·92	Uranium	U	238·2
Lanthanum	La	139·0	Vanadium	V	51·0
Lead	Pb	207·2	Xenon	Xe	130·2
Lithium	Li	6·94	Ytterbium	Yb	173·5
Lutecium	Lu	175·0	Yttrium	Yt	89·33
Magnesium	Mg	24·32	Zinc	Zn	65·37
Manganese	Mn	54·93	Zirconium	Zr	90·6
Mercury	Hg	200·6			

COMPARISON OF SCALES OF RELATIVE DENSITIES

°Tw.	Sp. Gr.	°Bé.	°Tw.	Sp. Gr.	°Bé.	°Tw.	Sp. Gr.	°Bé.	°Tw.	Sp. Gr.	°Bé.
0	1·000	0	44	1·220	26·0	88	1·440	44·1	132	1·660	57·4
1	1·005	·7	45	1·225	26·4	89	1·445	44·4	133	1·665	57·7
2	1·010	1·4	46	1·230	26·9	90	1·450	44·8	134	1·670	57·9
3	1·015	2·1	47	1·235	27·4	91	1·455	45·1	135	1·675	58·2
4	1·020	2·7	48	1·240	27·9	92	1·460	45·4	136	1·680	58·4
5	1·025	3·4	49	1·245	28·4	93	1·465	45·8	137	1·685	58·7
6	1·030	4·1	50	1·250	28·8	94	1·470	46·1	138	1·690	58·9
7	1·035	4·7	51	1·255	29·3	95	1·475	46·4	139	1·695	59·2
8	1·040	5·4	52	1·260	29·7	96	1·480	46·8	140	1·700	59·5
9	1·045	6·0	53	1·265	30·2	97	1·485	47·1	141	1·705	59·7
10	1·050	6·7	54	1·270	30·6	98	1·490	47·4	142	1·710	60·0
11	1·055	7·4	55	1·275	31·1	99	1·495	47·8	143	1·715	60·2
12	1·060	8·0	56	1·280	31·5	100	1·500	48·1	144	1·720	60·4
13	1·065	8·7	57	1·285	32·0	101	1·505	48·4	145	1·725	60·6
14	1·070	9·4	58	1·290	32·4	102	1·510	48·7	146	1·730	60·9
15	1·075	10·0	59	1·295	32·8	103	1·515	49·0	147	1·735	61·1
16	1·080	10·6	60	1·300	33·3	104	1·520	49·4	148	1·740	61·4
17	1·085	11·2	61	1·305	33·7	105	1·525	49·7	149	1·745	61·6
18	1·090	11·9	62	1·310	34·2	106	1·530	50·0	150	1·750	61·8
19	1·095	12·4	63	1·315	34·6	107	1·535	50·3	151	1·755	62·1
20	1·100	13·0	64	1·320	35·0	108	1·540	50·6	152	1·760	62·3
21	1·105	13·6	65	1·325	35·4	109	1·545	50·9	153	1·765	62·5
22	1·110	14·2	66	1·330	35·8	110	1·550	51·2	154	1·770	62·8
23	1·115	14·9	67	1·335	36·2	111	1·555	51·5	155	1·775	63·0
24	1·120	15·4	68	1·340	36·6	112	1·560	51·8	156	1·780	63·2
25	1·125	16·0	69	1·345	37·0	113	1·565	52·1	157	1·785	63·5
26	1·130	16·5	70	1·350	37·4	114	1·570	52·4	158	1·790	63·7
27	1·135	17·1	71	1·355	37·8	115	1·575	52·7	159	1·795	64·0
28	1·140	17·7	72	1·360	38·2	116	1·580	53·0	160	1·800	64·2
29	1·145	18·3	73	1·365	38·6	117	1·585	53·3	161	1·805	64·4
30	1·150	18·8	74	1·370	39·0	118	1·590	53·6	162	1·810	64·6
31	1·155	19·3	75	1·375	39·4	119	1·595	53·9	163	1·815	64·8
32	1·160	19·8	76	1·380	39·8	120	1·600	54·1	164	1·820	65·0
33	1·165	20·3	77	1·385	40·1	121	1·605	54·4	165	1·825	65·2
34	1·170	20·9	78	1·390	40·5	122	1·610	54·7	166	1·830	65·5
35	1·175	21·4	79	1·395	40·8	123	1·615	55·0	167	1·835	65·7
36	1·180	22·0	80	1·400	41·2	124	1·620	55·2	168	1·840	65·9
37	1·185	22·5	81	1·405	41·6	125	1·625	55·5	169	1·845	66·1
38	1·190	23·0	82	1·410	42·0	126	1·630	55·8	170	1·850	66·3
39	1·195	23·5	83	1·415	42·3	127	1·635	56·0	171	1·855	66·5
40	1·200	24·0	84	1·420	42·7	128	1·640	56·3	172	1·860	66·7
41	1·205	24·5	85	1·425	43·1	129	1·645	56·6	173	1·865	67·0
42	1·210	25·0	86	1·430	43·4	130	1·650	56·9			
43	1·215	25·5	87	1·435	43·8	131	1·655	57·1			

VAPOUR TENSION OF WATER.

° C.	Atmospheres.	° C.	Atmospheres.
40	·072	105	1·193
45	·094	110	1·415
50	·121	115	1·673
55	·154	120	1·962
60	·196	125	2·294
65	·246	130	2·671
70	·306	135	3·097
75	·380	140	3·575
80	·466	145	4·112
85	·570	150	4·712
90	·691	155	5·380
95	·834	160	6·120
100	1·000		

SULPHURIC ACID (AT 15° C.).

° Tw.	Per cent. of H_2SO_4.	° Tw.	Per cent. of H_2SO_4.	° Tw.	Per cent. of H_2SO_4.	° Tw.	Per cent. of H_2SO_4.
2	1·57	48	32·28	94	56·90	140	77·17
4	3·03	50	33·43	96	57·83	142	78·04
6	4·49	52	34·57	98	58·74	144	78·92
8	5·96	54	35·71	100	59·70	146	79·80
10	7·37	56	36·87	102	60·65	148	80·68
12	8·77	58	38·03	104	61·59	150	81·56
14	10·19	60	39·19	106	62·53	152	82·44
16	10·90	62	40·35	108	63·43	154	83·32
18	12·99	64	41·50	110	64·26	156	84·50
20	14·35	66	42·66	112	65·08	158	85·70
22	15·71	68	43·74	114	65·90	160	86·90
24	17·01	70	44·82	116	66·71	162	88·30
26	18·31	72	45·88	118	67·59	164	90·05
28	19·61	74	46·94	120	68·51	165	91·00
30	20·91	76	48·00	122	69·43	166	92·10
32	22·19	78	49·06	124	70·32	167	93·43
34	23·47	80	50·11	126	71·16	168	95·60
36	24·76	82	51·15	128	71·99	168·3*	97·70
38	26·04	84	52·15	130	72·82	168·1	98·70
40	27·32	86	53·11	132	73·64	168	99·20
42	28·58	88	54·07	134	74·51	167·7	99·95
44	29·84	90	55·03	136	75·42		
46	31·11	92	55·97	138	76·30		

* Greatest density.

HYDROCHLORIC ACID (AT 15° C.).

° Tw.	Per cent. of HCl.	° Tw.	Per cent. of HCl.	° Tw.	Per cent. of HCl.	° Tw.	Per cent. of HCl.
1	1·15	11	11·18	21	20·97	31	30·55
2	2·14	12	12·19	22	21·92	32	31·52
3	3·12	13	13·19	23	22·86	33	32·49
4	4·13	14	14·17	24	23·82	34	33·46
5	5·15	15	15·16	25	24·78	35	34·42
6	6·15	16	16·15	26	25·75	36	35·39
7	7·15	17	17·13	27	26·70	37	36·31
8	8·16	18	18·11	28	27·66	38	37·23
9	9·16	19	19·06	29	28·61	39	38·16
10	10·17	20	20·01	30	29·57	40	39·11

NITRIC ACID (AT 15° C.).

° Tw.	Per cent. HNO_3.	° Tw.	Per cent. HNO_3.	° Tw.	Per cent. HNO_3.	° Tw.	Per cent. HNO_3.
2	1·9	28	23·3	54	42·9	80	65·3
4	3·7	30	24·8	56	44·1	82	67·5
6	5·5	32	26·4	58	45·9	84	69·8
8	7·3	34	27·9	60	47·5	86	72·2
10	9·0	36	29·4	62	49·1	88	74·7
12	10·7	38	30·9	64	50·7	90	77·3
14	12·3	40	32·4	66	52·4	92	80·0
16	13·9	42	33·8	68	54·1	94	82·9
18	15·5	44	35·3	70	55·8	96	86·0
20	17·1	46	36·8	72	57·6	98	89·6
22	18·7	48	38·3	74	59·4	100	94·1
24	20·2	50	39·8	76	61·3	102	98·1
26	21·8	52	41·3	78	63·2	104	99·7

ACETIC ACID (AT 15° C.).

Per cent. $CH_3.COOH$.	Sp. Gr.	Per cent. $CH_3.COOH$.	Sp. Gr.	Per cent. $CH_3.COOH$.	Sp. Gr.	Per cent. $CH_3.COOH$.	Sp. Gr.
2	1·0022	28	1·0388	54	1·0646	80	1·0748
4	1·0052	30	1·0412	56	1·0660	82	1·0746
6	1·0083	32	1·0436	58	1·0673	84	1·0742
8	1·0113	34	1·0459	60	1·0685	86	1·0736
10	1·0142	36	1·0481	62	1·0697	88	1·0726
12	1·0171	38	1·0502	64	1·0707	90	1·0713
14	1·0200	40	1·0523	66	1·0717	92	1·0696
16	1·0228	42	1·0543	68	1·0725	94	1·0674
18	1·0256	44	1·0562	70	1·0733	96	1·0644
20	1·0284	46	1·0580	72	1·0740	98	1·0604
22	1·0311	48	1·0598	74	1·0744	100	1·0553
24	1·0337	50	1·0615	76	1·0747	* Greatest density.	
26	1·0363	52	1·0631	78*	1·0748		

FORMIC ACID (AT 20° C.).

Per cent. HCOOH.	Sp. Gr.	Per cent. HCOOH.	Sp. Gr.	Per cent. HCOOH.	Sp. Gr.	Per cent. HCOOH.	Sp. Gr.
2	1·0045	20	1·0489	50	1·1208	80	1·1861
4	1·0094	25	1·0610	55	1·1321	85	1·1954
6	1·0142	30	1·0730	60	1·1425	90	1·2045
8	1·0197	35	1·0848	65	1·1544	95	1·2141
10	1·0247	40	1·0964	70	1·1656	100	1·2213
15	1·0371	45	1·1086	75	1·1770		

SODIUM HYDROXIDE (AT 20° C.).

Per cent. NaHO.	Sp. Gr.	Per cent. NaHO.	Sp. Gr.	Per cent. NaHO.	Sp. Gr.	Per cent. NaHO.	Sp. Gr.
1	1·012	16	1·180	31	1·343	46	1·499
2	1·023	17	1·192	32	1·353	47	1·508
3	1·035	18	1·202	33	1·363	48	1·519
4	1·046	19	1·213	34	1·374	49	1·529
5	1·059	20	1·225	35	1·384	50	1·540
6	1·070	21	1·236	36	1·395	51	1·550
7	1·081	22	1·247	37	1·405	52	1·560
8	1·092	23	1·258	38	1·415	53	1·570
9	1·103	24	1·269	39	1·426	54	1·580
10	1·115	25	1·270	40	1·437	55	1·591
11	1·126	26	1·290	41	1·447	56	1·601
12	1·137	27	1·300	42	1·457	57	1·711
13	1·148	28	1·310	43	1·468	58	1·722
14	1·159	29	1·321	44	1·478	59	1·733
15	1·170	30	1·332	45	1·488	60	1·743

AMMONIA (AT 15° C.).

Sp. Gr.	Per cent. NH_3.	Sp. Gr.	Per cent. NH_3.	Sp. Gr.	Per cent. NH_3.	Sp. Gr.	Per cent. NH_3.
1·000	·00	·970	7·31	·940	15·63	·910	24·99
·998	·45	·968	7·82	·938	16·22	·908	25·65
·996	·91	·966	8·33	·936	16·82	·906	26·31
·994	1·37	·964	8·84	·934	17·42	·904	26·98
·992	1·84	·962	9·35	·932	18·03	·902	27·65
·990	2·31	·960	9·91	·930	18·64	·900	28·33
·988	2·80	·958	10·47	·928	19·25	·898	29·01
·986	3·30	·956	11·03	·926	19·87	·896	29·69
·984	3·80	·954	11·60	·924	20·49	·894	30·37
·982	4·30	·952	12·17	·922	21·12	·892	31·05
·980	4·80	·950	12·74	·920	21·75	·890	31·75
·978	5·30	·948	13·31	·918	22·39	·888	32·50
·976	5·80	·946	13·88	·916	23·03	·886	33·25
·974	6·30	·944	14·46	·914	23·68	·884	34·10
·972	6·80	·942	15·04	912	24·33	·882	34·95

GLOSSARY

Acid.—A compound, containing hydrogen, which can react with oxides and hydroxides of the metals to produce water and another substance called a salt.

$$\begin{aligned} \text{Acid} + \text{Oxide} &\rightarrow \text{Water} + \text{Salt}. \\ 2\text{HCl} + \text{MgO} &= \text{H}_2\text{O} + \text{MgCl}_2. \\ \text{Acid} + \text{Hydroxide} &\rightarrow \text{Water} + \text{Salt}. \\ 2\text{HCl} + \text{Mg(HO)}_2 &= 2\text{H}_2\text{O} + \text{MgCl}_2. \end{aligned}$$

The metal replaces the whole or only part of the hydrogen of the acid. The hydrogen may, in many cases, be replaced directly by the metal.

$$\begin{aligned} \text{Acid} + \text{Metal} &\rightarrow \text{Hydrogen} + \text{Salt}. \\ \text{H}_2\text{SO}_4 + \text{Zn} &= \text{H}_2 + \text{ZnSO}_4. \end{aligned}$$

Aqueous solutions of most acids turn blue litmus red, and have a sour taste.

Acid oxide.—See Anhydride.

Acid salts.—See Basicity. Acid salts are not always acid to litmus though they contain hydrogen, which can be replaced directly by a metal, *e.g.* sodium bicarbonate, $NaHCO_3$, and disodium hydrogen phosphate, Na_2HPO_4, are slightly alkaline to litmus. It is therefore preferable to avoid the use of the term acid in the naming of these substances.

Alkali.—A basic oxide or hydroxide (see Bases) which is soluble in water. The solution turns red litmus blue.

Amide.—An organic compound which is formed from an organic acid by the replacement of the $-OH$ by an $-NH_2$ group. Thus, acetic acid having the formula CH_3COOH, acetamide is $CH_3 . CONH_2$.

Amphoteric oxide.—An oxide which behaves as a basic oxide to certain acid oxides and as an acid oxide to certain basic oxides. Thus lead oxide forms lead sulphate, $PbO . SO_3$, and sodium plumbite, $Na_2O . PbO$; aluminium oxide forms aluminium sulphate, $Al_2O_3 . 3SO_3$, and sodium aluminate, $3Na_2O . Al_2O_3$ or Na_3AlO_3.

Anhydride.—An oxide which, when united with water, forms an acid.

Anilide.—An organic compound similar to an amide (see above) containing the group C_6H_5NH- in place of the $-OH$ group of the organic acid. Acetanilide is $CH_3 . CONH . C_6H_5$.

Anode.—See Electrodes.

✓**Atom.**—The smallest portion of an element which can form part of a molecule.

✓**Atomic weight.**—The weight of an atom of an element compared with the weight of an atom of oxygen taken as 16. For the atomic weights of the elements see page 174.

Base.—A metallic oxide which unites with an acid oxide to form a salt only, or with an acid to form a salt and water. The hydroxides of the metals are also spoken of as bases. In organic chemistry the term includes all substances which are capable of uniting directly with acids, thus aniline, $C_6H_5NH_2$, is a base because, like ammonia, NH_3, it unites directly to form salts such as $C_6H_5NH_2 . HCl$.

Basicity.—The basicity of an acid is measured by the number of atoms of hydrogen in a molecule of the acid which can be replaced by a metal. Hydrochloric acid, HCl, and nitric acid, HNO_3, are **monobasic**, and only one class of salts is possible. Thus, hydrochloric acid forms chlorides as NaCl and $CaCl_2$, and nitric acid forms nitrates as $NaNO_3$ and $Ca(NO_3)_2$. Sulphuric acid, H_4SO_2, is **dibasic**, and can form two classes of salts, viz.: *normal* salts and *acid* salts (see acid salts). Normal salts are formed by the replacement of both atoms of hydrogen by a metal, *e.g.* sodium sulphate, Na_2SO_4, and magnesium sulphate, $MgSO_4$. Acid salts (hydrogen salts or bi-salts) are formed by the replacement of one atom of hydrogen, *e.g.* sodium bisulphate, $NaHSO_4$.

Sulphurous acid, H_2SO_3, is also dibasic and phosphoric acid, H_3PO_4, is **tribasic**. Acetic acid, CH_3COOH, and formic acid, HCOOH, though each contains more than one atom of hydrogen in a molecule, are monobasic, the only hydrogen capable of replacement by a metal being that united to oxygen in the acid, or carboxyl, group $-COOH$. Oxalic acid, $(COOH)_2$, is dibasic, and citric acid, $CH_2 . COOH . COH . COOH . CH_2 . COOH$ is tribasic.

Basic oxide.—See Base.

Basic salt.—A salt in which the basic oxide is not united with the quantity of acid oxide necessary to give the normal salt, and is therefore capable of uniting with more of the acid oxide, or of reacting with an acid, to produce the normal salt and water.

Cathode.—See Electrodes.

✓**Chemical change.**—A change in the composition of a substance. It is always accompanied by a physical change, *i.e.* by a change of temperature, colour, volume, etc.

✓**Compound.**—A substance formed by the union of two or more elements. It differs from a mixture because (*a*) the elements are always present in the same proportion; (*b*) its properties are different from those of its constituents; (*c*) its constituents cannot be separated by mechanical means; (*d*) when a compound is made there is always a physical change.

Condition.—The state or condition of a textile material with respect to the amount of moisture it contains.

Deliquescence.—The property possessed by some solids of absorbing moisture from the air and becoming damp. Calcium chloride, magnesium chloride, and zinc chloride are deliquescent.

Desiccating agent.—A substance capable of absorbing moisture, and used for drying gases. Examples: strong sulphuric acid, phosphorus pentoxide, and all deliquescent substances.

Diazotisation.—The production of diazo compounds by the action of nitrous acid on aromatic amines. Thus, aniline, $C_6H_5NH_2$, and similar substances are acted upon by nitrous acid in the presence of a little dilute hydrochloric acid, and form compounds containing two nitrogen atoms linked together. Aniline gives $C_6H_5 . N_2 . Cl$. These diazo compounds have the property of reacting with (coupling) certain organic compounds, *e.g.* phenol, β naphthol, etc., to produce coloured substances. The diazotisation of the wool substance is therefore considered as an indication of the presence of the $-NH_2$ group in the substance (see page 24).

Efflorescence.—The property, possessed by certain substances containing water of crystallisation, of giving up part or the whole of this water when exposed to the air. Examples: washing soda, $Na_2CO_3 . 10H_2O$, a colourless crystalline substance gives up water and falls to powder, forming $Na_2CO_3 . H_2O$.

Electrodes.—The surfaces at which the current enters and leaves a liquid during electrolysis. The surface at which the current enters is called the anode, and that at which it leaves is called the cathode.

✓**Electrolysis.**—The splitting up of a substance by the passage of electricity through its solution or through the substance itself in the molten state.

✓**Element.**—A substance which cannot be split up into two or more substances.

Fehling's solution.—A solution prepared in two parts as follows:

(*a*) Dissolve 6.93 grams of blue vitriol in 100 c.c. of water.

(*b*) Dissolve 1.73 grams of Rochelle salt (sodium potassium tartrate) and 5.16 grams of caustic soda in 100 c.c. of water. Equal volumes of (*a*) and (*b*) are mixed before use.

The solution is reduced by grape sugar giving a red precipitate of cuprous oxide, Cu_2O. Fehling's solution is reduced by hydrocellulose (page 85).

✓**Formula.**—A representation of the composition of a molecule. Examples: H_2 represents a molecule of hydrogen; H_2O, a molecule of water; H_2SO_4, a molecule of sulphuric acid.

Hydrolysis.—The breaking up of a substance into two or more substances by the addition to the substance of the elements of water (see Soaps, page 121).

Hydrometer.—An instrument for showing directly the specific gravity of a liquid by the depth to which the instrument sinks, when placed in the liquid.

It consists of a graduated tube made to float vertically by means of a bulb below, suitably weighted with shot or mercury.

The scale on the hydrometer may be marked to show the specific gravity, or to give the corresponding readings on the Twaddell, Beaumé, or other scale.

Hydroxide.—A compound of a basic oxide with water. Examples: sodium hydroxide ($Na_2O + H_2O = 2NaHO$), calcium hydroxide ($CaO + H_2O = Ca(HO)_2$).

Hygrometer.—An instrument for measuring the amount of water vapour in the air or, more frequently, the hygrometric state or relative humidity.

✓**Humidity.**—Relative humidity is generally meant by this term. The relative humidity is the ratio of the amount of water vapour actually present in the air to the amount required for complete saturation at the existing temperature.

✓**Mixture.**—A substance formed by mixing two or more substances together. The composition of a mixture may be altered; its properties lie between those of its constituents; its constituents can be separated by mechanical means; and, when the mixture is made, there is no physical change (see Compound).

✓**Molecular weight.**—The weight of a molecule of a substance compared with the weight of an atom of oxygen taken as 16. The weight of a molecule of a substance is, therefore, the sum of the weights of the atoms in the molecule.

✓**Molecule.**—The smallest portion of a substance which can exist by itself.

Nascent.—An adjective applied to the state of elements just liberated from their compounds in the form of atoms and before they unite among themselves to form molecules.

The atoms thus set free are unable to exist for an appreciable length of time, and therefore unite with those substances present for which they have the greatest affinity. The bleaching by chlorine water is explained by some as due to the liberation of nascent oxygen from the water by the chlorine

$$\text{Chlorine} + \text{Water} \rightarrow \text{Hydrochloric acid} + \text{Nascent oxygen.}$$
$$Cl_2 + H_2O = 2HCl + O.$$

The atoms of oxygen are assumed to unite with the colouring matter.

Neutralisation.—The addition of an acid to an alkali until the product is neutral to (*i.e.* produces no change with) an indicator, such as litmus, methyl orange, etc.

Neutral oxide.—An oxide which is neither basic nor acidic, *e.g.* nitric oxide, NO, and carbon monoxide, CO.

Oxide.—A compound of an element and oxygen. Oxides may be divided into acid oxides, basic oxides, peroxides, and neutral oxides.

Oxidising agent.—A substance which gives oxygen to another substance.

Though not complete, the above definition will be sufficient for the purposes in which it is used in these pages. Chlorine water, nitric acid, dichromates are examples of oxidising agents.

Peroxide.—A metallic oxide containing more oxygen than the oxide which corresponds to the common series of salts of the metal. Lead monoxide, PbO, is the basic oxide corresponding to the common series of lead salts, $PbCl_2$, $PbSO_4$, $Pb(NO_3)_2$, etc., and therefore red lead, Pb_3O_4, and lead dioxide, PbO_2, are peroxides. Similarly manganese dioxide, MnO_2, and barium dioxide, BaO_2, are peroxides.

Peroxides give off oxygen when heated with strong sulphuric acid and chlorine with strong hydrochloric acid.

✓**Physical change.**—A change in the properties of a substance not involving a change in the composition of the substance.

Radicle or Radical.—A group of atoms which, in many of the reactions of the compound containing it, behaves as a single atom. The group NH_4 –

behaves in many cases as an atom of an alkali metal, and is given the name ammonium. Many examples are met with in organic compounds.

Reducing agent.—A substance which takes away oxygen from a compound. Sulphurous acid (p. 58), formic, lactic, and oxalic acids (p. 152), are examples.

Saponification.—The formation of a soap.

Salt.—A compound formed by the replacement of the hydrogen of an acid by a metal. Salts may be produced in many ways :

1. By the direct union of a metal and another element. (This only applies to the formation of chlorides, bromides, iodides, sulphides, etc., that is, to salts of acids composed of hydrogen and another element.)

Sodium + Chlorine→Sodium chloride.

$$2Na + Cl_2 = 2NaCl.$$

2. By the action of a metal on the acid

Zinc + Acid →Zinc salt.

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

3. By the action of the oxide of the metal on the acid

Zinc oxide + Acid →Zinc salt + Water.

$$ZnO + H_2SO_4 = ZnSO_4 + H_2O.$$

4. By the action of the hydroxide on the acid

Zinc hydroxide + Acid →Zinc salt + Water.

$$Zn(HO)_2 + H_2SO_4 = ZnSO_4 + H_2O.$$

In 3 and 4. only water is produced in addition to the salt (see Basic oxide).

Ammonium salts are produced by neutralising an acid with a solution of ammonia in water (ammonium hydroxide) $NH_4 . HO$.

Ammonium hydroxide + Acid →Ammonium salt + Water.

$$2NH_4HO + H_2SO_4 = (NH_4)_2SO_4 + H_2O.$$

5. By the action of the carbonate on the acid

Calcium carbonate + Acid →Calcium salt + Water + Carbon dioxide.

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2.$$

The carbonates may be considered as compounds of a basic oxide and carbon dioxide, and the carbon dioxide, being a gas, is liberated.

6. Insoluble or only slightly soluble salts may be produced by precipitation.

Soluble calcium salt + A soluble carbonate → Insoluble calcium carbonate.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

Separating funnel.—A funnel having a tap fitted in the stem. A mixture of two immiscible liquids may be separated by placing it in the funnel and running off the lower liquid.

Specific gravity.—The weight of a certain volume of a substance compared with the weight of an equal volume of water at the same temperature.

Symbol.—A sign representing one atom of an element. Thus, H represents one atom of hydrogen ; O, one atom of oxygen ; and C, one atom of carbon.

Valency.—The combining power of an atom of an element compared with the combining power of an atom of hydrogen. It is measured by the number of atoms of hydrogen which can unite with, or be replaced by, one atom of the element. The table below gives the valencies of some of the commoner elements.

Univalent.	Bivalent.	Tervalent.	Quadrivalent.
H	Ca	$Fe^{(ic)}$	$Sn^{(ic)}$
Na	Mg	Al	
K	Zn	Bi	
Ag	$Fe^{(ous)}$	Sb	
NH_4 –	Cu	Cr	

The formulae of many of the compounds of the above elements can be formed, if the formulae of the corresponding hydrogen compounds be known, by substituting an atom of the element for its equivalent number of hydrogen atoms thus

Oxides—H_2O, Na_2O, ZnO, Al_2O_3.
Hydroxides—HHO, $NaHO$, $Zn(HO)_2$, $Al(HO)_3$.
Chlorides—HCl, $NaCl$, $ZnCl_2$, $AlCl_3$.
Sulphates—H_2SO_4, Na_2SO_4, $ZnSO_4$, $Al_2(SO_4)_3$,

and so on

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